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RESOURCE AND ENVIRONMENTAL PROFILE ANALYSIS OF NINE BEVERAGE CONTAINER ALTERNATIVES

Environmental Protection Agency
Library Systems Branch, Room 2903
401 M Street, S.W.
Washington, D.C. 20460

DRAFT FINAL REPORT
February 6, 1974

MRI Project No. 3794-D

Volume II

Data and Calculation

For

Environmental Protection Agency
Office of Solid Waste Management Programs
Washington, D.C. 20460

Attn: Ms. Eileen Claussen
Resource Recovery Division

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CHAPTER I

BASIC ENERGY IMPACT FACTORS

This chapter contains data and information used to convert raw fuel and electric energy input values into corresponding environmental impact parameters. The basic factors are discussed in three sections:

A. Mobile and Stationary Sources
B. Electric Energy
C. Transportation

A. Mobile and Stationary Sources

A set of atmospheric emission factors resulting from the combustion of fuels has been developed by the authors of this report in cooperation with the Physical Sciences Division of Midwest Research Institute (MRI). They are reported in Table 1. These data represent both a comprehensive literature search and data collected from a nationwide telephone survey. The factors represent national average emissions after pollution controls have been applied. They are representative of levels actually experienced in 1971.

Factors relating to both precombustion and combustion impacts are included. Combustion factors relate only to impacts resulting from combustion of fuel and exclude secondary (or precombustion) environmental effects. The environmental effects of combustion of gasoline include an energy consumption of 125 x 10^6 Btu and the generation of 10 pounds of particulate air pollution, etc., for the consumption of 1,000 gallons of gasoline. These factors are listed in the "combustion" column for gasoline in Table 1. The combustion impacts are listed for each fuel category in that table.

Secondary impacts are incurred in mining coal, refining oil and so on. To include these secondary factors, tables similar to Tables 2, and 3 were derived for each fuel category making use of the combustion factors in Table 1. These secondary factors are combined with the primary combustion factors to yield a new set of factors for fuel combustion similar to those shown in the "total" columns of Table 1. These modified factors were then used to recalculate the quantities of Tables 2 and 3. This modification resulted in only small changes in Tables 2 and 3 and performing one more iteration insures that all secondary and higher order impacts are included. Thus, Tables 1, 2 and 3 include all secondary or higher order environmental impacts relating to fuel combustion. Table 1 lists the precombustion impacts first, then the combustion impacts for each fuel category. The total column is the sum of the combustion and precombustion impacts.

TABLE 1

ENVIRONMENTAL IMPACTS RESULTING FROM FUEL COMBUSTION

	Gasoline (1,000 gal.)			Diesel (1,000 gal.)			Fuel Oil Mobile Source (1,000 gal.)			Natural Gas Internal Combustion (1,000 cu ft)			Natural Gas Industrial Heating (1,000 cu ft)			Natural Gas Utility Heating (1,000 cu ft)		
	Precombustion	Combustion	Total	Precombustion	Combustion	Total	Precombustion	Combustion	Total	Precombustion	Combustion	Total	Precombustion	Combustion	Total	Precombustion	Combustion	Total
Energy--10^5 Btu	16	125	141	16	139	155	16	150	166	0.3	1.03	1.33	0.3	1.03	1.33	0.3	1.03	1.33
Water volume--gal.	9,000	-	9,000	9,000	-	9,000	9,000	-	9,000	18	-	18	18	-	18	18	-	18
Solid wastes--lb	24	-	24	24	-	24	24	-	24	-	-	-	-	-	-	-	-	-
Atmospheric emissions--lb																		
Particulates	7	10	17	7	13	20	7	200	207	0.008	-	0.008	0.008	0.018	0.026	0.008	0.015	0.023
Nitrogen oxides	20	177	197	20	500	520	20	150	170	1.6	4.8	6.4	1.6	0.214	1.8	1.6	0.39	2.0
Hydrocarbons	43	295	338	43	35	78	43	150	193	1.4	0.8	2.2	1.4	0.04	1.44	1.4	0.04	1.44
Sulfur oxides	30	6	36	30	27	57	30	150	180	0.02	-	0.02	0.02	-	0.02	0.02	-	0.02
Carbon monoxide	8	1,254	1,260	8	250	258	8	50	58	0.05	1.6	2.1	0.5	-	0.5	0.5	-	0.5
Aldehydes	0.6	12	13	0.6	3	3.6	0.6	10	10.6	-	-	-	-	0.002	0.002	-	0.001	0.001
Other organics	0.5	44	5	0.5	3	3.5	0.5	-	0.5	-	-	-	-	0.005	0.005	-	0.003	0.003
Ammonia	0.4	-	0.4	0.4	-	0.4	0.4	-	0.4	-	-	-	-	-	-	-	-	-
Lead	0.003	3	3.0	0.003	-	0.003	0.003	-	0.003	-	-	-	-	-	-	-	-	-
Total Atmospheric	109	1,761	1,869	109	831	940	109	710	819	3.6	7.2	10.7	3.6	0.28	3.9	3.6	0.45	4.0
Waterborne wastes--lb																		
Dissolved solids (oil field brine)	75	-	75	75	-	75	75	-	75	0.22	-	0.22	0.22	-	0.22	0.22	-	0.22
Other	2	-	2	2	-	2	2	-	2	-	-	-	-	-	-	-	-	-
Total Waterborne	77	-	77	77	-	77	77	-	77	0.22	-	0.22	0.22	-	0.22	0.22	-	0.22

	Residual Oil Industrial Heating (1,000 gal.)			Fuel Oil Utility Heating (1,000 gal.)			Distillate Oil Industrial Heating (1,000 gal.)			Coal Industrial Heat (1 ton)			Coal Utility Heat (1 ton)			Diesel Locomotive (1,000 gal.)		
	Precombustion	Combustion	Total	Precombustion	Combustion	Total	Precombustion	Combustion	Total	Precombustion	Combustion	Total	Precombustion	Combustion	Total	Precombustion	Combustion	Total
Energy--10^6 Btu	16	150	166	16	148	164	16	139	155	0.4	26.2	26.6	0.4	26.2	26.6	16	139	155
Water volume--gal.	9,000	-	9,000	9,000	-	9,000	9,000	-	9,000	87	-	87	87	-	87	9,000	-	9,000
Solid wastes--lb	24	-	24	24	-	24	24	-	24	380	380	760	380	280	660	24	-	24
Atmospheric emissions--lb																		
Particulates	7	23	30	7	10	17	7	15	22	4	52	56	4	21	25	7	25	32
Nitrogen oxides	20	72	92	20	100	120	20	72	92	1	20	21	1	20	21	20	75	95
Hydrocarbons	43	2	45	43	3	46	43	2	45	1	1	2	1	0.2	1.2	43	50	93
Sulfur oxides	30	300	330	30	300	330	30	75	105	3	110	113	3	110	113	30	65	95
Carbon monoxide	8	0.2	8.2	8	0.04	8	8	0.2	8.2	5	3	8	5	0.5	5.5	8	70	78
Aldehydes	0.6	2	2.6	0.6	1.0	1.6	0.6	2	2.6	0.02	0.005	0.025	0.02	0.005	0.025	0.6	4	4.6
Other organics	0.5	-	0.5	0.5	-	0.5	0.5	-	0.5	0.04	-	0.04	0.04	-	0.04	0.5	7	7.5
Ammonia	0.4	-	0.4	0.4	-	0.4	0.4	-	0.4	-	-	-	-	-	-	0.4	-	0.4
Lead	0.003	-	0.003	0.003	-	0.003	0.003	-	0.003	-	-	-	-	-	-	0.003	-	0.003
Total Atmospheric	109	399	509	109	414	523	109	166	276	14	186	200	14	152	166	109	296	405
Waterborne wastes--lb																		
Dissolved solids (oil field brine)	75	-	75	75	-	75	75	-	75	-	-	-	-	-	-	75	-	75
Acid	-	-	-	-	-	-	-	-	-	4	-	4	4	-	4	-	-	-
Metal ions	-	-	-	-	-	-	-	-	-	1	-	1	1	-	1	-	-	-
Other	2	-	2	2	-	2	2	-	2	1	-	1	1	-	1	2	-	2
Total Waterborne	77	-	77	77	-	77	77	-	77	6	-	6	6	-	6	77	-	77

Source: Midwest Research Institute.

TABLE 2

PRECOMBUSTION ENVIRONMENTAL IMPACTS RESULTING FROM PRODUCTION AND PROCESSING OF 1,000 CUBIC FEET OF NATURAL GAS

	Production	Processing	Transportation	Total
Energy--10^6 Btu	0.025	0.32	0.01	0.35
Water volume--gal.	2	16	0.1	18
Atmospheric emissions--lb				
Particulates	0.004	0.004	--	0.008
Nitrogen oxides	0.096	1.44	0.05	1.59
Hydrocarbons	0.49	0.92	0.02	1.43
Sulfur oxides	0.007	0.017	--	0.024
Carbon monoxide	0.040	0.48	0.02	0.54
Total Atmospheric	0.64	2.86	0.09	3.59
Waterborne wastes--lb				
Dissolved solids (oil field brine)	0.18	0.043	--	0.22

Source: Chapter III, pp. 71-76.

TABLE 3

PRECOMBUSTION ENVIRONMENTAL IMPACTS RESULTING FROM PRODUCTION, REFINING AND DELIVERY OF 1,000 GALLONS OF LIQUID HYDROCARBON FUEL

	Production	Refining	Transportation	Total
Energy--10^6 Btu	1.3	10.9	3.8	16.0
Water volume--gal.	-	9.000	-	9.000
Atmospheric emissions--lb				
Particulate	0.76	3.17	3.6	7.5
Nitrogen oxides	2.43	11.3	6.5	20.2
Hydrocarbon	10.3	28.6	4.6	43.5
Sulfur oxide	1.6	25.6	3.0	30.2
Carbon monoxide	1.9	3.17	2.95	8.0
Aldehydes	0.03	0.34	0.21	0.58
Other organics	0.006	0.37	0.14	0.52
Ammonia	-	0.39	-	0.39
Lead	-	-	0.003	0.003
Total Atmospheric	17	73	21	111
Waterborne wastes--lb				
Dissolved solids (oil field brine)	71.8	1.4	1.5	74.7
Suspended solids	-	0.46	0.01	0.47
BOD	-	0.23	-	0.23
COD	-	0.78	0.02	0.80
Phenol	-	0.06	-	0.06
Sulfide	-	0.085	0.002	0.087
Oil	-	0.13	-	0.013
Acid	0.05	0.14	0.004	0.19
Metal ion	0.01	0.04	-	0.05
Total Waterborne	71.8	3.3	1.5	76.6

Source: Chapter III, p. 67-70.

The inclusion of precombustion impacts of fuels has a significant effect on all of the fuel categories. One important effect is on the environmental profile of coal combustion. The inclusion of waterborne acid and metal ions resulting from acid drainage of coal mines introduces a water pollution impact which must be assigned to coal. As will be seen in several subsequent appendices, the use of coal as a fuel contributes significantly to the water pollution impact in the overall environmental profiles of several container systems.

The natural gas combustion profile is considerably altered by the inclusion of natural gas production and processing. Approximately 22 percent of the energy and 97 percent of the air pollution for natural gas shown in Table 1 is from precombustion operations. This circumstance results primarily from natural gas processing which requires large amounts of energy to liquefy and to remove various natural gas components from well-head streams before sending the methane rich gas to consumers.

The effect on liquid hydrocarbon fuels is less dramatic, but still significant. Precombustion energy requirements are approximately 10 percent of the total, whereas precombustion air pollution for gasoline is about 4 percent and for different fuel oils ranges from 10 to 40 percent. A significant water pollution factor is introduced by including oilfield brines.

B. Electric Energy

The environmental impacts associated with use of electrical energy are summarized in Table 4. The impacts were calculated on the basis of a composite kilowatt-hour (kwhr). A composite kilowatt-hour is defined as one kilowatt-hour generated by the national average mix of fossil fuels and hydroelectric power. Data were obtained from the Edison Electric Institute for 1969.[82] Impact factors from Table 1 were combined with the fuel quantities to arrive at the values in Table 4.

Of particular interest in this table is the significant water pollution associated with electric energy use. This impact is due to acid coal mine drainage. Thus, one of the most important, and large, impacts cannot be controlled easily by the ultimate electricity consumer nor by the generating company.

TABLE 4

ENVIRONMENTAL IMPACTS RESULTING FROM GENERATION AND DELIVERY OF 1,000 COMPOSITE KILOWATT-HOURS OF ELECTRICITY, 1969

	Coal	Oil	Natural Gas	Total
Quantity	0.24 Ton	8.0 Gal.	2,660 Cu Ft	-
Percent of Btu	59	13	28	100
Impacts				
Energy--10^6 Btu[a]	6.9	1.6	3.9	12.4
Water volume--gal.	21	72	48	141
Solid wastes--lb				
Mining	91	-	-	91
Fuel combustion[b]	60	-	-	60
Atmospheric emissions--lb				
Particulates	6.0	0.14	0.06	6.2
Nitrogen oxides	5.0	0.96	5.0	11.0
Hydrocarbons	0.29	0.37	3.8	4.5
Sulfur oxides	27	2.64	0.06	29.7
Carbon monoxide	1.3	0.06	1.3	2.7
Aldehydes	0.006	0.01	0.003	0.019
Other	0.01	0.007	0.008	0.025
Total Atmospheric	39.6	4.19	10.2	54
Waterborne wastes--lb				
Acid	0.96	-	0.01	0.97
Metal ion	0.24	-	-	0.24
Other	0.2	0.60	0.56	1.36
Total Waterborne	1.4	0.60	0.60	2.57

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a/ These values were derived from Reference 82.

b/ There are 67 pounds of solids produced, but 7 pounds are recovered for sale as an aggregate, or other use.

Source: Table 1, 82.

C. Transportation

Environmental impacts occur when goods are transported because of the consumption of fossil fuels to provide necessary energy. In this study, the modes of transportation included are rail, truck, pipeline and barge. These impacts were calculated by determining the kinds and amounts of fuels used by each mode on a national average basis. Impacts were then calculated for 1,000 ton-miles.

1. Rail: The latest complete set of fuel consumption data indicate that diesel fuel accounted for 98 percent of the energy expended by railroads in 1968. We assumed that 100 percent of the energy was supplied by diesel fuel and that 5.63×10^{14} Btu of fuel were used.93/ This fuel use resulted in 7.68×10^{11} ton-miles of transportation.93/ The corresponding fuel consumption was 5.25 gallons per 1,000 ton-miles. This value was combined with information in Table 1 to yield the impacts presented in Table 5.

2. Truck: In 1967, a total of 9.29×10^{9} miles were traveled by trucks engaged in intercity highway hauling. This resulted in 1.10×10^{11} ton-miles of transportation.84/ It is estimated that 35 percent of these miles were traveled by gasoline engine trucks while 65 percent were traveled by diesel fueled trucks.91/ National average fuel mileage data are not available, but a reasonable assumption based on actual experience is that this type of truck travel results in fuel consumption rates of about 5 miles per gallon for either type of fuel. Thus, 6.5×10^{8} gallons of gasoline and 1.20×10^{9} gallons of diesel fuel were used in 1967. From this it was calculated that 5.9 gallons of gasoline and 10.9 gallons of diesel fuel were consumed per 1,000 ton-miles. Using data in Table 1, impacts were calculated and are reported in Table 5.

3. Barge: During 1966, barge traffic resulted in 5.0×10^{11} ton-miles of transportation.86/ Fuel consumption was 6.99×10^{8} gallons of diesel fuel and 3.09×10^{9} gallons of residual.100/ Therefore, 1.4 gallons of diesel fuel and 6.1 gallons of residual were consumed per 1,000 ton-miles. Again, impacts were calculated and are listed in Table 5.

4. Crude oil and products pipeline: Sources in the pipeline industry report that, on the average, about 30 cubic feet of natural gas fuel are required to transport one barrel of oil 300 miles through a pipeline. This requirement translates to 30 cubic feet for 45 ton-miles, or 0.67 cubic feet of natural gas per ton-mile of crude petroleum transportation. This factor, combined with information from Table 1 enabled us to calculate the impacts for 1,000 ton-miles of pipeline transportation. Pipeline transportation impacts for moving other types of liquids of interest in this study were assumed to be approximately the same as for crude oil.

TABLE 5

FUEL CONSUMPTION AND ENVIRONMENTAL IMPACTS RESULTING FROM 1,000 TON-MILES OF TRANSPORTATION BY EACH MODE

	Rail	Truck	Barge	Pipeline
Fuel				
Gasoline--gal.	-	5.9	-	-
Diesel--gal.	5.25	10.9	1.4	-
Fuel oil--gal.	-	-	6.1	-
Natural gas--cu ft	-	-	-	670
Energy--10^6 Btu	0.81	2.5	1.2	0.89
Water volume--gal.	47	151	67	12
Solid wastes (fuel combustion)--lb	0.1	0.4	0.2	-
Atmospheric emissions--lb				
Particulates	0.17	0.32	1.29	0.005
Nitrogen oxides	0.50	6.83	1.77	4.22
Hydrocarbon	0.49	2.84	1.28	1.47
Sulfur oxides	0.50	0.83	1.18	0.013
Carbon monoxide	0.41	10.2	0.72	1.41
Aldehydes	0.024	0.12	0.070	-
Other organics	0.039	0.067	0.008	-
Ammonia	0.002	0.007	0.003	-
Lead	-	0.018	-	-
Total Atmospheric	2.1	21.3	6.3	7.1
Waterborne wastes--lb				
Suspended solids (oil field brine)	0.39	1.26	0.56	0.15
COD	0.004	0.013	0.006	-
Acid	0.001	0.003	0.001	-
Metal ion	-	0.001	-	-
Other	0.009	0.013	0.013	-
Total Waterborne	0.40	1.29	0.58	0.15

Source: Midwest Research Institute.

According to the data of Table 5, transportation by truck is the most environmentally detrimental of the four transportation modes. This result is due to the relative inefficiency of the gasoline engine. Truck transportation ranks highest in every impact category. Computer analysis comparing the four transport modes showed that the impact index for trucks is more than double that of barge transportation, greater than triple that of rail transportation and nearly five times worse than pipeline transport.

CHAPTER II

GLASS BOTTLES

This chapter contains the basic data and outlines the calculations made to determine the resource and environmental profiles of glass beverage containers. Eight basic container systems are considered. Of these eight, four are returnable systems and four are one-way systems. The four returnable systems are three beer systems with differing trip rates and paper packaging options, and one soft drink system. The four one-way systems are the conventional beer and soft drink containers, a hypothetical one-way from recycled glass and a plastic coated glass one-way designed for beer. Details for these systems are shown in Figures 1 and 2, and Table 6. Figure 1 is an overall glass container system flow diagram, Figure 2 and Table 6 provide numerical material summaries.

This chapter discusses glass bottle systems in the following sequence.

A. General Discussion of Computer Generated Tables
B. Overview
C. Glass Sand Mining
D. Limestone Mining
E. Lime Manufacture
F. Natural Soda Ash Mining
G. Soda Ash Manufacture
H. Feldspar Mining
I. Glass Container Manufacture
J. Closures
K. Plastic Coated Bottles
L. Paper Packaging
M. Bottle Filling
N. Solid Waste Disposal
O. Nonreturnable and Returnable Glass Containers
P. Glass Recycling

A. General Discussion of Computer Generated Tables

Table 7 is in the form that all computer generated tables in this report will duplicate, and the discussion that follows can be generalized to all of those computer tables. The table is divided into three main sections: (1) input to systems, (2) output from systems, and (3) summaries.

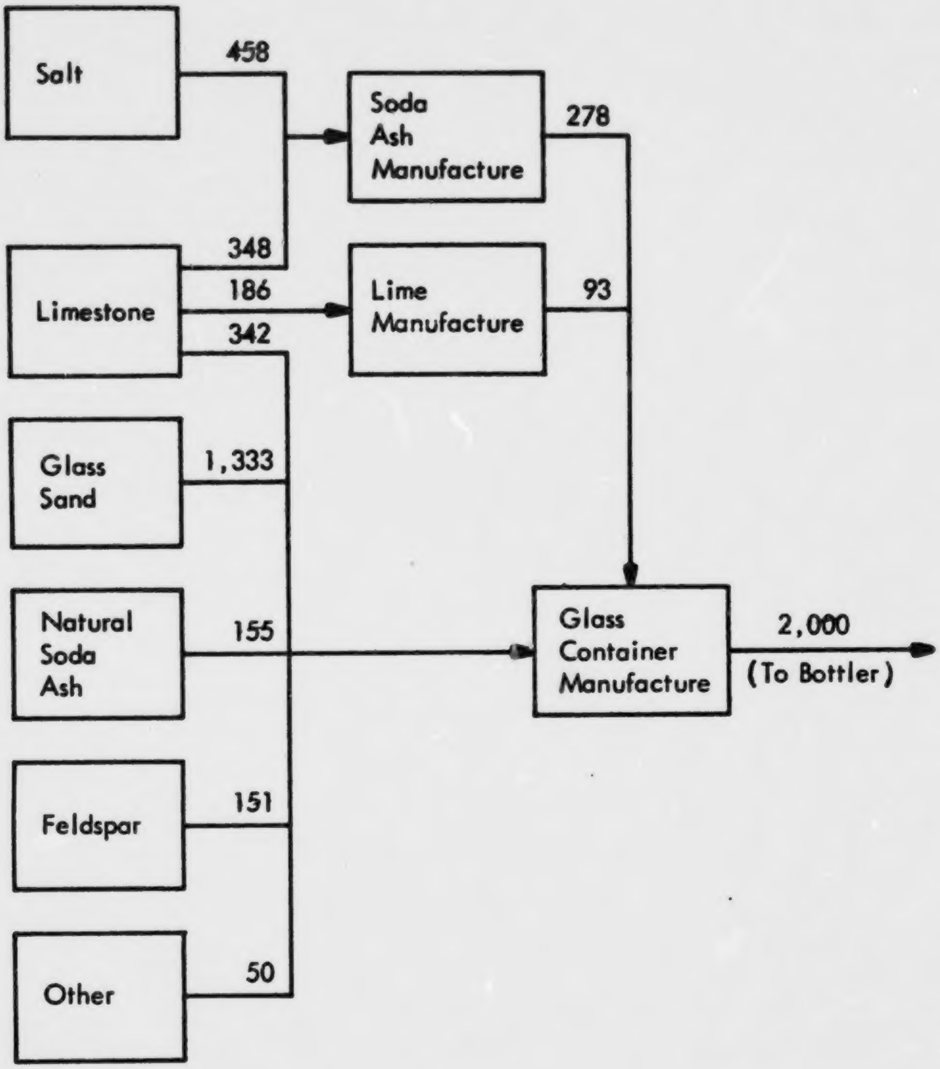
Salt
458
Soda
Ash
Manufacture
278
348
Limestone
186
342
Lime
Manufacture
93
Glass
Sand
1,333
Natural
Soda
Ash
155
Glass
Container
Manufacture
2,000
(To Bottler)
Feldspar
151
Other
50

Figure 1 - Materials Requirements for the Manufacture of 1 Ton Glass (pounds)

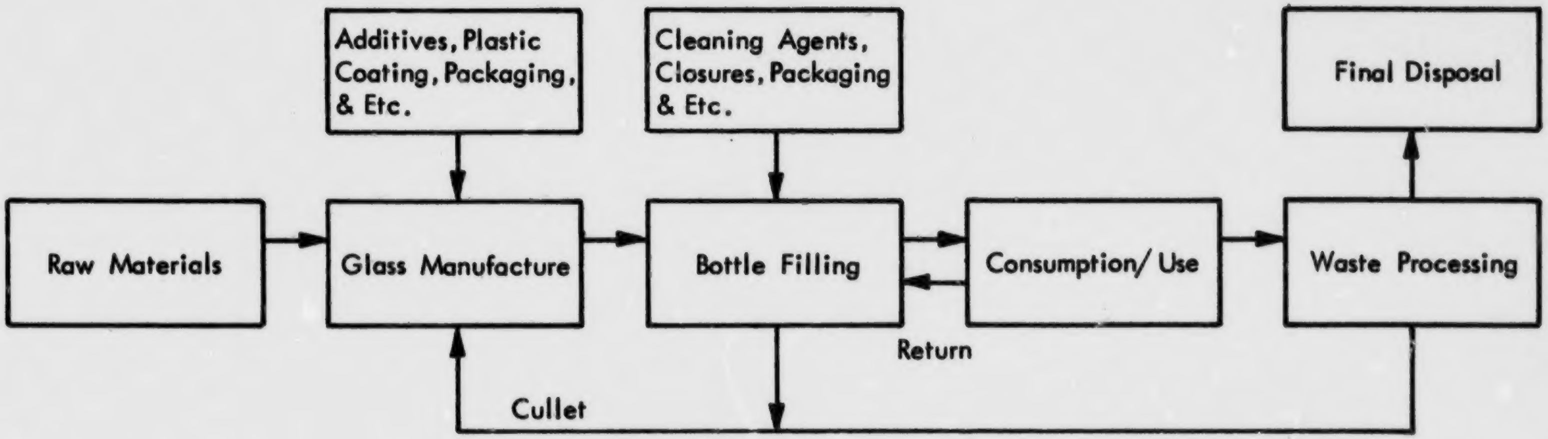
Additives, Plastic Coating, Packaging, & Etc.
Cleaning Agents, Closures, Packaging & Etc.
Final Disposal
Raw Materials
Glass Manufacture
Bottle Filling
Consumption/ Use
Waste Processing
Return
Cullet

Figure 2 - Materials Flow for Glass Container Systems

TABLE 6

CONTAINER RELATED MATERIALS REQUIRED FOR 1 MILLION FILLINGS (TONS)

	Returnable Bottles				One-Way Bottles			
	19 Trip On-Premise (Three-Trip Paper Packaging)	10 Trip Off-Premise (Three-Trip Paper Packaging)	5 Trip Off-Premise (One-Trip Paper Packaging)	15 Trip Soft Drink (Three-Trip Paper Packaging	Soft Drink	Plastic Coated	Recycled Glass	Conventional Glass
Glass Containers	16	30	61	22	260	173	205	205
Closures	2	2	2	2	2	2	2	2
Paper Packaging								
Corrugated	13	13	39	1.4	22	11.4	13.5	13.5
Bleached Kraft	-	5.7	17	7.3	14.3	29	29	29
Cleaning Agents	1.5	1.5	1.5	1.25	-	-	-	-
Plastic Coat	-	-	-	-	-	2.2	-	-

Note: All container volumes were 12 ounces, except 15-trip soft drink which was 16 ounces.
All containers were for beer, except the two specified for soft drink.

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TABLE 7

IMPACTS FOR 1 MILLION GLASS CONTAINERS

INPUT TO SYSTEMS

MATERIALS NAME	UNITS	19 TRIP ON PREM RETURN GLASS	10 TRIP OFF PREM RETURN GLASS	5 TRIP OFF PREM RETURN GLASS	PLASTIC COATED GLASS	ONE WAY GLASS 100 PCNT RECYCLE	ONE WAY GLASS	Soft Drink 15-Trip Return	Soft Drink One-Way Glass
MATERIAL [illegible] FIBER	POUNDS	28442.	41110.	120339.	82101.	87976.	86041.	14162.	62627.
MATERIAL LIMESTONE	POUNDS	15497.	28047.	54445.	153112.	1649.	177303.	23247.	224431.
MATERIAL IRON ORE	POUNDS	3416.	3816.	3816.	3816.	3816.	3818.	3816.	3820.
MATERIAL SALT	POUNDS	16552.	17203.	31194.	80272.	0.	93093.	14145.	118869.
MATERIAL GLASS SAND	POUNDS	21120.	40260.	80520.	231000.	2706.	267890.	33800.	339760.
MATERIAL NAT SODA ASH	POUNDS	2644.	4727.	4455.	27125.	0.	31457.	[illegible]	39897.
MATERIAL FELDSPAR	POUNDS	2416.	4605.	9211.	26425.	0.	30645.	3775.	38867.
MATERIAL BAUXITE ORE	POUNDS	0.	0.	0.	0.	0.	0.	0.	0.
MATERIAL PROCESS ADD	POUNDS	3132.	4441.	11354.	13343.	6517.	14752.	2614.	15331.
ENERGY PROCESS	MIL BTU	1166.	1917.	3891.	5736.	7794.	6218.	1433.	7032.
ENERGY TRANSPORT	MIL BTU	259.	301.	481.	523.	424.	559.	217.	518.
ENERGY OF MATL RESOURCE	MIL BTU	1.	1.	1.	108.	1.	1.	1.	1.
WATER VOLUME	THOU GAL	1080.	1440.	3042.	3274.	2700.	3450.	1008.	2961.

OUTPUT FROM SYSTEMS

MATERIALS NAME	UNITS	19 TRIP ON PREM RETURN GLASS	10 TRIP OFF PREM RETURN GLASS	5 TRIP OFF PREM RETURN GLASS	PLASTIC COATED GLASS	ONE WAY GLASS 100 PCNT RECYCLE	ONE WAY GLASS	Soft Drink 15-Trip Return	Soft Drink One-Way Glass
SOLID WASTES PROCESS	POUND	13434.	21422.	42265.	101373.	18513.	115977.	16055.	141701.
SOLID WASTES FUEL COMB	POUND	2513.	3710.	9656.	9598.	14644.	10066.	2429.	9501.
SOLID WASTES MINING	POUND	22100.	28533.	44284.	88313.	29575.	99285.	25427.	120218.
SOLID WASTE POST-CONSUM	CUBIC FT	872.	1121.	2708.	3484.	1443.	3841.	821.	3425.
ATMOS PARTICULATES	POUND	1435.	2168.	5335.	6578.	4815.	7219.	1369.	7341.
ATMOS NITROGEN OXIDES	POUND	1724.	2321.	4380.	6888.	7924.	7407.	1402.	8485.
ATMOS HYDROCARBONS	POUND	1117.	1494.	2617.	4853.	5017.	6908.	1338.	5905.
ATMOS SULFUR OXIDES	POUND	2091.	2682.	6154.	6123.	10138.	6636.	1947.	7178.
ATMOS CARBON MONOXIDE	POUND	1030.	1309.	2286.	3253.	3165.	3491.	1472.	4082.
ATMOS ALDEHYDES	POUND	14.	17.	29.	36.	55.	39.	17.	42.
ATMOS OTHER ORGANICS	POUND	22.	30.	63.	57.	60.	50.	20.	55.
ATMOS ODOROUS SULFUR	POUND	234.	364.	1061.	808.	855.	840.	188.	579.
ATMOS AMMONIA	POUND	27.	42.	72.	183.	16.	211.	35.	264.
ATMOS HYDROGEN FLUORIDE	POUND	0.	0.	0.	0.	0.	0.	0.	0.
ATMOS LEAD	POUND	1.	1.	2.	2.	2.	2.	3.	3.
ATMOS MERCURY	POUND	0.	0.	0.	0.	0.	0.	0.	0.
ATMOSPHERIC CHLORINE	POUNDS	13.	13.	13.	0.	0.	0.	11.	0.
WATERBORNE FLUORIDES	POUND	0.	0.	0.	0.	0.	0.	0.	0.
WATERBORNE DISS SOLIDS	POUND	334.	433.	775.	1133.	1705.	1175.	298.	1286.
WATERBORNE BOD	POUND	1493.	1883.	3592.	1914.	2026.	1986.	428.	1391.
WATERBORNE PHENOL	POUND	0.	0.	1.	1.	1.	1.	0.	1.
WATERBORNE SULFIDES	POUND	0.	0.	1.	1.	1.	1.	0.	1.
WATERBORNE OIL	POUND	6.	9.	15.	40.	45.	44.	7.	54.
WATERBORNE COD	POUND	2.	3.	5.	17.	13.	6.	2.	6.
WATERBORNE SUSP SOLIDS	POUND	1533.	1808.	2405.	2759.	2529.	2843.	[illegible]	2341.
WATERBORNE ACID	POUND	46.	60.	117.	154.	186.	165.	53.	181.
WATERBORNE METAL ION	POUND	12.	15.	28.	38.	47.	41.	13.	45.
WATERBORNE CHEMICALS	POUND	0.	0.	0.	0.	0.	0.	0.	0.
WATERBORNE CYANIDE	POUND	0.	0.	0.	0.	0.	0.	0.	0.
WATERBORNE ALKALINITY	POUND	0.	0.	0.	0.	0.	0.	0.	0.
WATERBORNE CHROMIUM	POUND	0.	0.	0.	0.	0.	0.	1009.	0.
WATERBORNE IRON	POUND	0.	0.	0.	0.	0.	0.	0.	0.
WATERBORNE [illegible]	POUND	0.	0.	0.	0.	0.	0.	0.	0.
WATERBORNE [illegible]	POUND	0.	0.	0.	0.	0.	0.	0.	0.
WATERBORNE [illegible]	POUND	0.	0.	0.	0.	0.	0.	0.	0.
WATERBORNE L[illegible]	POUND	0.	0.	0.	0.	0.	0.	[illegible]	0.

TABLE 7 (Concluded)

SUMMARY OF SYSTEMS

		15 TRIP ON PREM RETURN GLASS	10 TRIP OFF PREM RETURN GLASS	5 TRIP OFF PREM RETURN GLASS	PLASTIC COATED GLASS	ONE WAY GLASS 100 PCNT RECYCLE	ONE WAY GLASS	Soft Drink 15-Trip Return	Soft Drink One-Way Glass
SUMMARY OF ENVIRONMENTAL IMPACTS									
NAME	UNITS								
RAW MATERIALS	POUNDS	87406.	144261.	320333.	617194.	102664.	705004.	102699.	842810.
ENERGY	MIL BTU	1626.	2219.	4373.	6367.	8219.	6778.	1651.	7550.
WATER	THOU GAL	1060.	1440.	3042.	3274.	2700.	3450.	1000.	2961.
INDUSTRIAL SOLID WASTES	CUBIC FT	514.	731.	1299.	2690.	847.	3042.	605.	3665.
ATM EMMISSIONS	POUNDS	7713.	10440.	21931.	28781.	32049.	30813.	8001.	33934.
WATERBORNE WASTES	POUNDS	3528.	4211.	7434.	6058.	6553.	6261.	3463.	5306.
POST-CONSUMER SOL WASTE	CUBIC FT	672.	1121.	2708.	3484.	1443.	3841.	821.	3425.
INDEX OF ENVIRONMENTAL IMPACTS									
NAME	STANDARD VALUES								
RAW MATERIALS	80231.	110	180	399	769	128	879	128	1050
ENERGY	953.	171	233	459	668	862	711	173	792
WATER	447.	237	322	680	732	603	771	223	662
INDUSTRIAL SOLID WASTES	365.	141	200	355	736	232	832	166	1003
ATM EMMISSIONS	4292.	180	243	511	671	747	718	186	791
WATERBORNE WASTES	1006.	351	419	739	602	651	622	344	528
POST-CONSUMER SOL WASTE	433.	155	259	625	804	333	886	189	790
UNWEIGHTED INDEX		1345	1856	3768	4982	3556	5419	1409	5616
WEIGHTED INDEX OF ENVIRONMENTAL IMPACTS									
NAME	WEIGHT								
RAW MATERIALS	.05	5	9	20	38	6	44	6	53
ENERGY	.40	68	93	184	267	345	284	69	317
WATER	.05	12	16	34	37	30	39	11	33
INDUSTRIAL SOLID WASTES	.05	7	10	18	37	12	42	8	50
ATM EMMISSIONS	.20	36	49	102	134	149	144	37	158
WATERBORNE WASTES	.20	70	84	148	120	130	124	69	106
POST-CONSUMER SOL WASTE	.05	8	13	31	40	17	44	9	40
WEIGHTED COMPOSITE INDEX		206	274	537	673	689	721	209	757
RANK OF SYSTEMS		1	2	3	4	5	6	1	2

At the top of Table 7 we see the input to systems section. In that section is found a detailed display of the amounts of materials, energy and water input to each of the eight systems considered here. For example, the first number in the first column shows that the total manufacturing system for 1 million 19-trip on-premise returnable glass bottles (starting from extraction of raw materials from the ground through final disposal) requires 28,992 pounds of wood fiber.

The second section of the table shows the output from the systems, measured in terms of the solid wastes, atmospheric emissions and water pollutants.

Finally, the lower section contains a summary of the first two sections. The summary table is divided into three subsections: (1) summary of environmental impacts, (2) index of environmental impacts, and (3) weighted index of environmental impacts. The summary of environmental impacts subsection aggregates the data shown in the top two sections into seven categories. For example, all data lines near the top of Table 7 which begin with the word "material" are summed and listed in the summary table on the line labeled "raw materials." Thus, the 19-trip system requires 87,906 pounds of "materials" for 1 million fillings. The other categories are aggregated in a similar manner.

The index of environmental impacts are derived to convert the direct data conversion numbers in the summary subsection to dimensionless ratios so that impacts with different units can be compared directly. Unweighted indices are derived by dividing each number in the Summary of Environmental Impacts section by the appropriate number in the standard value column. Any number may be chosen for the standard value. Usually, it is chosen simply as the sum of impact values across all subprocesses for each impact; or as the average impact--obtained by dividing the sum of impacts by the number of columns. In this case, it is the latter. Thus, the unweighted index for raw materials for the 19-trip system is 87,906 ÷ 329,560 x 100 = 27. Likewise, the unweighted index for energy for the 5-trip returnable system is (4,313 ÷ 4,930) x 100 = 89.

The unweighted indices can be added to get an unweighted composite index by summing the indices for each system. This allows a comparison between systems of total environmental impacts. However, the various impacts should be weighted since they are not equally important. For example, water use is not nearly as detrimental to the environment as energy use. These opinions are reflected in the column of weighting factors. Weighted index values are formed by multiplying each unweighted index by the appropriate weighting factor. For example, the weighted index for raw materials used in one-way containers is 214 x 0.05 = 11. Weighted index values can be summed to provide a composite index to compare the systems with one another.

The advantage of the weighted index system is that it provides a convenient means of comparing systems. It takes into account not only the rank of each system in each impact category, but also the magnitude of how much better or worse each system is as compared to the other systems. It also gives perspective to the importance of each category by weighting them. However, there are also some pitfalls of this type of analysis. One problem is that the outcome is dependent on the value chosen for weighting values. This problem is discussed thoroughly in Volume I, and is not a serious problem for this study.

Another important potential problem is that the index values are based on a standard value derived from a combination of numbers for all systems studied. The result of this is that the rank of the systems may change depending on what systems are included. That is, it is possible that a hypothetical system A may be better than B if X systems are included, but reducing the number of systems to Y may result in B showing up as better than A. We have performed on extensive computer analysis of this problem as it relates directly to this study and have found that this problem does not alter the outcome of this study.

The overview section of this chapter contains eight tables of the same type as Table 7. However, Table 14 contains basic data from which the other tables were derived. Table 14 results from computer calculations converting raw data into the various impact categories. For example, the first column on Table 14 is for glass sand mining. This column is based on Table 15, p. 35. The computer converts values such as 0.0058 ton coal (Table 15) into its various impacts, such as the air pollutants (Table 1), and aggregates the value for 1 ton of glass sand mining as shown in Table 14. These values, along with the other values are then combined to form the systems as shown in other tables, such as Table 7. This is done by using flow diagrams such as Figure 1, which shows that 1,333 pounds (0.666 ton) sand are required for 1 ton of glass manufacture. Then, finally the computer is instructed to include 16 tons of glass (Table 6) for 1 million fillings of a 19-trip returnable. The other data needed to build the systems are treated in the same fashion.

B. Overview

This section contains eight computer generated tables which summarize the environmental impacts of glass beer bottles. Table 7 displays the impacts for 1 million containers of each of the systems. Table 8 shows the impacts for 1 ton of nonreturnable bottles as allocated to each component process. Tables 9 and 10 present the impacts for returnable systems, also broken down by component processes. Table 11 presents the GCP System.

TABLE 8

IMPACTS FOR 1 TON OF THE ONE-WAY GLASS SYSTEM

INPUT TO SYSTEMS

MATERIALS NAME	UNITS	FELDSPAR MINING 151 LBS	GLASS SAND MINING 1333 LBS	SODA ASH MINING 155 LBS	SODA ASH MFG 278 LBS	LIME MFG 92 LBS	LIMESTON MINING 876 LBS	SALT MINING 454 LBS	GLASS CONT FAB 2000 LBS	DISPOSAL	STEEL CLOSURE 20 LBS	TRANS	FILLING BOTTLES 2000 LBS	PACKAGIN 404 LBS
MATERIAL WOOD FIBER	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	397.387
MATERIAL LIMESTONE	POUND	0.000	0.000	0.000	347.500	184.000	0.000	0.000	334.000	0.000	0.247	0.000	0.000	0.000
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	19.080	0.000	0.000	0.000
MATERIAL SALT	POUND	0.000	0.000	0.000	458.700	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1370.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	155.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	151.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	0.000	0.000	0.000	1.251	0.000	0.000	0.000	40.000	0.000	1.390	0.000	0.000	28.180
ENERGY PROCESS	MIL BTU	.060	.614	.049	1.883	.235	.019	.054	18.510	0.000	.526	0.000	.769	7.380
ENERGY TRANSPORT	MIL BTU	.047	.039	0.000	0.000	.002	.014	.005	.189	.135	.009	1.463	0.000	.727
ENERGY OF MATL RESOURCE	MIL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.005	0.000	0.000	0.000
WATER VOLUME	THOU GAL	.341	1.207	.093	2.294	.015	.041	.230	.168	.009	.537	.087	1.404	8.803

OUTPUT FROM SYSTEMS

MATERIALS NAME	UNITS	FELDSPAR MINING 151 LBS	GLASS SAND MINING 1333 LBS	SODA ASH MINING 155 LBS	SODA ASH MFG 278 LBS	LIME MFG 92 LBS	LIMESTON MINING 876 LBS	SALT MINING 458 LBS	GLASS CONT FAB 2000 LBS	DISPOSAL	STEEL CLOSURE 20 LBS	TRANS	FILLING BOTTLES 2000 LBS	PACKAGIN 404 LBS
SOLID WASTES PROCESS	POUND	0.000	0.000	0.000	444.260	16.790	0.000	0.000	45.000	0.000	8.179	0.000	9.000	25.503
SOLID WASTES FUEL COMB	POUND	.251	.544	0.000	.056	.076	.053	.012	15.415	.023	.404	.231	.506	29.726
SOLID WASTES MINING	POUND	345.345	2.270	9.240	18.223	1.685	.096	.017	22.081	0.000	66.584	0.000	2.715	19.631
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	18.202	0.000	0.000	0.000	0.000
ATMOS PARTICULATES	POUND	1.155	.284	.771	5.678	1.053	5.691	.007	3.980	.016	.535	.259	.360	13.975
ATMOS NITROGEN OXIDES	POUND	.207	.796	.063	1.504	.240	.059	.073	22.270	.180	.315	3.097	.780	6.294
ATMOS HYDROCARBONS	POUND	.055	.501	.053	.441	.128	.023	.063	16.987	.323	.446	1.443	.512	2.918
ATMOS SULFUR OXIDES	POUND	.138	.745	.001	6.188	.519	.038	.011	9.667	.034	.429	.622	1.084	12.482
ATMOS CARBON MONOXIDE	POUND	.111	.320	.018	.486	.001	.050	.025	6.437	1.834	.135	4.411	.219	2.591
ATMOS ALDEHYDES	POUND	.001	.003	.000	.007	.000	.001	.000	.048	.012	.001	.061	.003	.045
ATMOS OTHER ORGANICS	POUND	.001	.003	.000	.004	.001	.000	.000	.068	.123	.001	.046	.002	.033
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.021	0.000	0.000	3.842
ATMOS AMMONIA	POUND	.000	.000	0.000	.974	.000	.000	.000	.003	.000	.053	.004	.000	.005
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.000	.000	0.000	.000	.000	.000	.000	.000	.003	.000	.007	.000	.001
ATMOS MERCURY	POUND	.000	.000	0.000	.000	.000	.000	.000	.000	0.000	.000	0.000	.006	.000
ATMOSPHERIC CHLORINE	POUNDS	0.000	0.000	0.000	0.000	6.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	.027	.096	.006	.211	.021	.009	.011	3.081	.072	.046	.723	.128	1.227
WATERBORNE BOD	POUND	.000	.000	0.000	.000	.000	.000	.000	.007	.000	.000	.002	.000	9.137
WATERBORNE PHENOL	POUND	.000	.000	0.000	.001	.000	.000	.000	.001	.000	.000	.001	.000	.001
WATERBORNE SULFIDES	POUND	.000	.000	0.000	.000	.000	.000	.000	.001	.000	.000	.001	.000	.001
WATERBORNE OIL	POUND	.000	.000	0.000	.000	.000	.000	.000	.201	.000	.011	.001	.000	.001
WATERBORNE COD	POUND	.000	.000	0.000	.002	.000	.000	.000	.005	.001	.000	.008	.001	.010
WATERBORNE SUSP SOLIDS	POUND	.000	.065	0.000	.974	.000	.000	.004	.005	.000	4.873	.005	.000	7.026
WATERBORNE ACID	POUND	.004	.024	0.000	.197	.018	.001	.000	.233	.000	.090	.001	.028	.206
WATERBORNE METAL ION	POUND	.001	.006	0.000	.048	.004	.000	.000	.048	.000	.023	.000	.007	.052
WATERBORNE CHEMICALS	POUND	0.000	0.000	0.000	.001	0.000	0.000	0.000	0.000	0.000	.001	0.000	0.000	0.000
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE LEAD	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 8 (Concluded)

SUMMARY OF SYSTEMS

		FELDSPAR MINING 151 LBS	GLASS SAND MINING 1333 LBS	SODA ASH MINING 155 LBS	SODA ASH MFG 278 LBS	LIME MFG 92 LBS	LIMESTON MINING 876 LBS	SALT MINING 458 LBS	GLASS CONT FAB 2000 LBS	DISPOSAL	STEEL CLOSURE 20 LBS	TRANS	FILLING BOTTLES 2000 LBS	PACKAGIN 404 LBS
SUMMARY OF ENVIRONMENTAL IMPACTS NAME	UNITS													
RAW MATERIALS	POUNDS	0.000	0.000	0.000	807.451	184.000	0.000	0.000	2000.000	0.000	28.717	0.000	0.000	425.567
ENERGY	MIL BTU	.107	.654	.049	1.883	.236	.033	.059	18.699	.135	.539	1.463	.769	8.108
WATER	THOU GAL	.341	1.207	.093	2.294	.015	.041	.230	1.168	.009	.537	.087	1.484	8.803
INDUSTRIAL SOLID WASTES	CUBIC FT	4.666	.038	.125	6.514	.250	.002	.000	1.124	.000	1.016	.003	.177	1.011
ATM EMMISSIONS	POUNDS	1.668	2.652	.906	15.283	2.821	5.862	.180	59.459	2.534	1.936	9.951	2.961	42.185
WATERBORNE WASTES	POUNDS	.033	.791	.008	1.430	.044	.010	.011	3.589	.074	4.993	.742	.165	17.662
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	18.202	0.000	0.000	0.000	0.000
INDEX OF ENVIRONMENTAL IMPACTS NAME	STANDARD VALUES													
RAW MATERIALS	343.404	0	0	0	235	54	0	0	582	0	8	0	0	124
ENERGY	3.305	3	20	1	57	7	1	2	566	4	16	44	23	245
WATER	1.683	20	72	6	136	1	2	14	69	1	32	5	88	523
INDUSTRIAL SOLID WASTES	1.484	314	3	8	439	17	0	0	76	0	68	0	12	68
ATM EMMISSIONS	15.031	11	18	6	102	19	39	1	396	17	13	66	20	281
WATERBORNE WASTES	3.054	1	26	0	47	1	0	0	118	2	164	24	5	578
POST-CONSUMER SOL WASTE	1.874	0	0	0	0	0	0	0	0	971	0	0	0	0
UNWEIGHTED INDEX		349	139	21	1016	99	42	17	1807	995	301	139	148	1819
WEIGHTED INDEX OF ENVIRONMENTAL IMPACTS NAME	WEIGHT													
RAW MATERIALS	.05	0	0	0	12	3	0	0	29	0	0	0	0	6
ENERGY	.40	1	8	1	23	3	0	1	226	2	7	18	9	98
WATER	.05	1	4	0	7	0	0	1	3	0	2	0	4	26
INDUSTRIAL SOLID WASTES	.05	16	0	0	22	1	0	0	4	0	3	0	1	3
ATM EMMISSIONS	.20	2	4	1	20	4	8	0	79	3	3	13	4	56
WATERBORNE WASTES	.20	0	5	0	9	0	0	0	24	0	33	5	1	116
POST-CONSUMER SOL WASTE	.05	0	0	0	0	0	0	0	0	49	0	0	0	0
WEIGHTED COMPOSITE INDEX		20	21	2	93	11	8	2	365	54	48	36	19	305

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TABLE 9

IMPACTS FOR 1 MILLION 5-TRIP OFF-PREMISE RETURNABLE GLASS BOTTLES

INPUT TO SYSTEMS

MATERIALS

NAME	UNITS	BOTTLE SYSTEM 61 TONS	FILLING	PACKAGE	DISPOSAL	TRANS	STEEL CLOSURE 4000 LBS
MATERIAL WOOD FIBER	POUNDS	0.	0.	122279.	0.	0.	0.
MATERIAL LIMESTONE	POUND	52795.	0.	0.	0.	0.	1649.
MATERIAL IRON ORE	POUND	0.	0.	0.	0.	0.	3816.
MATERIAL SALT	POUND	27981.	3213.	0.	0.	0.	0.
MATERIAL GLASS SAND	POUND	80520.	0.	0.	0.	0.	0.
MATERIAL NAT SODA ASH	POUND	9455.	0.	0.	0.	0.	0.
MATERIAL FELDSPAR	POUND	9211.	0.	0.	0.	0.	0.
MATERIAL BAUXITE ORE	POUND	0.	0.	0.	0.	0.	0.
MATERIAL PROCESS ADD	POUNDS	2516.	49.	8648.	0.	0.	278.
ENERGY PROCESS	MIL BTU	1307.	478.	2031.	0.	0.	105.
ENERGY TRANSPORT	MIL BTU	18.	0.	215.	12.	237.	2.
ENERGY OF MATL RESOURCE	MIL BTU	0.	0.	0.	0.	0.	1.
WATER VOLUME	THOU GAL	329.	421.	2199.	1.	14.	107.

OUTPUT FROM SYSTEMS

MATERIALS

NAME	UNITS	BOTTLE SYSTEM 61 TONS	FILLING	PACKAGE	DISPOSAL	TRANS	STEEL CLOSURE 4000 LBS
SOLID WASTES PROCESS	POUND	32089.	2036.	6594.	0.	0.	1636.
SOLID WASTES FUEL COMB	POUND	1001.	272.	6370.	2.	37.	97.
SOLID WASTES MINING	POUND	24386.	1168.	5473.	0.	0.	13317.
SOLID WASTE POST-CONSUM	CUBIC FT	0.	0.	0.	2590.	0.	0.
ATMOS PARTICULATES	POUND	1165.	105.	3955.	1.	41.	107.
ATMOS NITROGEN OXIDES	POUND	1538.	506.	1764.	17.	437.	63.
ATMOS HYDROCARBONS	POUND	1113.	373.	805.	30.	216.	89.
ATMOS SULFUR OXIDES	POUND	1056.	434.	4548.	3.	108.	86.
ATMOS CARBON MONOXIDE	POUND	459.	137.	743.	306.	609.	27.
ATMOS ALDEHYDES	POUND	4.	2.	13.	1.	9.	0.
ATMOS OTHER ORGANICS	POUND	5.	2.	9.	37.	8.	0.
ATMOS ODOROUS SULFUR	POUND	0.	0.	1073.	0.	0.	4.
ATMOS AMMONIA	POUND	60.	0.	1.	0.	1.	11.
ATMOS HYDROGEN FLUORIDE	POUND	0.	0.	0.	0.	0.	0.
ATMOS LEAD	POUND	0.	0.	0.	0.	1.	0.
ATMOS MERCURY	POUND	0.	0.	0.	0.	0.	0.
ATMOSPHERIC CHLORINE	POUNDS	0.	13.	0.	0.	0.	0.
WATERBORNE FLUORIDES	POUND	0.	0.	0.	0.	0.	0.
WATERBORNE DISS SOLIDS	POUND	211.	97.	360.	7.	117.	9.
WATERBORNE BOD	POUND	0.	1000.	2631.	0.	0.	0.
WATERBORNE PHENOL	POUND	0.	0.	0.	0.	0.	0.
WATERBORNE SULFIDES	POUND	0.	0.	0.	0.	0.	0.
WATERBORNE OIL	POUND	12.	0.	0.	0.	0.	2.
WATERBORNE COD	POUND	1.	0.	3.	0.	1.	0.
WATERBORNE SUSP SOLIDS	POUND	100.	260.	1598.	0.	1.	965.
WATERBORNE ACID	POUND	29.	8.	57.	0.	0.	18.
WATERBORNE METAL ION	POUND	7.	2.	14.	0.	0.	5.
WATERBORNE CHEMICALS	POUND	0.	0.	0.	0.	0.	0.
WATERBORNE CYANIDE	POUND	0.	0.	0.	0.	0.	0.
WATERBORNE ALKALINITY	POUND	0.	0.	0.	0.	0.	0.
WATERBORNE CHROMIUM	POUND	0.	0.	0.	0.	0.	0.
WATERBORNE IRON	POUND	0.	0.	0.	0.	0.	0.
WATERBORNE ALUMINUM	POUND	0.	0.	0.	0.	0.	0.
WATERBORNE NICKEL	POUND	0.	0.	0.	0.	0.	0.
WATERBORNE MERCURY	POUND	0.	0.	0.	0.	0.	0.
WATERBORNE LEAD	POUND	0.	0.	0.	0.	0.	0.

TABLE 9 (Concluded)

		SUMMARY OF SYSTEMS					
		BOTTLE SYSTEM 61 TONS	FILLING	PACKAGE	DISPOSAL	TRANS	STEEL CLOSURE 4000 LBS
SUMMARY OF ENVIRONMENTAL IMPACTS							
NAME	UNITS						
RAW MATERIALS	POUNDS	182479.	3261.	130927.	0.	0.	5743.
ENERGY	MIL BTU	1325.	478.	2246.	12.	237.	108.
WATER	THOU GAL	329.	421.	2199.	1.	14.	107.
INDUSTRIAL SOLID WASTES	CUBIC FT	776.	47.	276.	0.	1.	203.
ATM EMMISSIONS	POUNDS	5419.	1572.	12911.	396.	1430.	387.
WATERBORNE WASTES	POUNDS	361.	1368.	4644.	7.	120.	999.
POST-CONSUMER SOL WASTE	CUBIC FT	0.	0.	0.	2590.	0.	0.
INDEX OF ENVIRONMENTAL IMPACTS							
NAME	STANDARD VALUES						
RAW MATERIALS	32033.	570	10	409	0	0	18
ENERGY	437.	303	109	514	3	54	25
WATER	304.	108	138	723	0	5	35
INDUSTRIAL SOLID WASTES	130.	597	36	212	0	0	156
ATM EMMISSIONS	2193.	247	72	589	18	65	18
WATERBORNE WASTES	743.	49	184	625	1	16	134
POST-CONSUMER SOL WASTE	271.	0	0	0	957	0	0
UNWEIGHTED INDEX		1874	549	3072	979	140	386
WEIGHTED INDEX OF ENVIRONMENTAL IMPACTS							
NAME	WEIGHT						
RAW MATERIALS	.05	28	1	20	0	0	1
ENERGY	.40	121	44	205	1	22	10
WATER	.05	5	7	36	0	0	2
INDUSTRIAL SOLID WASTES	.05	30	2	11	0	0	8
ATM EMMISSIONS	.20	49	14	118	4	13	4
WATERBORNE WASTES	.20	10	37	125	0	3	27
POST-CONSUMER SOL WASTE	.05	0	0	0	48	0	0
WEIGHTED COMPOSITE INDEX		243	105	515	53	38	52

TABLE 10

IMPACTS FOR 1 MILLION 19-TRIP ON PREM RET GLS

INPUT TO SYSTEMS

MATERIALS

NAME	UNITS	POLYSTY FOAM JACKET 4400 LBS	GLASS SYSTEM FILLING ETC.
MATERIAL WOOD FIBER	POUNDS	0.	82101.
MATERIAL LIMESTONE	POUND	0.	153112.
MATERIAL IRON ORE	POUND	0.	3816.
MATERIAL SALT	POUND	0.	80272.
MATERIAL GLASS SAND	POUND	0.	231000.
MATERIAL NAT SODA ASH	POUND	0.	27125.
MATERIAL FELDSPAR	POUND	0.	26425.
MATERIAL BAUXITE ORE	POUND	0.	0.
MATERIAL PROCESS ADD	POUNDS	22.	13321.
ENERGY PROCESS	MIL BTU	179.	5557.
ENERGY TRANSPORT	MIL BTU	0.	523.
ENERGY OF MATL RESOURCE	MIL BTU	107.	1.
WATER VOLUME	THOU GAL	39.	3235.

OUTPUT FROM SYSTEMS

MATERIALS

NAME	UNITS	POLYSTY FOAM JACKET 4400 LBS	GLASS SYSTEM FILLING ETC.
SOLID WASTES PROCESS	POUND	299.	101074.
SOLID WASTES FUEL COMB	POUND	250.	9348.
SOLID WASTES MINING	POUND	376.	87938.
SOLID WASTE POST-CONSUM	CUBIC FT	0.	3484.
ATMOS PARTICULATES	POUND	27.	5551.
ATMOS NITROGEN OXIDES	POUND	283.	6604.
ATMOS HYDROCARBONS	POUND	505.	4347.
ATMOS SULFUR OXIDES	POUND	139.	5984.
ATMOS CARBON MONOXIDE	POUND	85.	3168.
ATMOS ALDEHYDES	POUND	0.	35.
ATMOS OTHER ORGANICS	POUND	0.	57.
ATMOS ODOROUS SULFUR	POUND	0.	808.
ATMOS AMMONIA	POUND	0.	183.
ATMOS HYDROGEN FLOURIDE	POUND	0.	0.
ATMOS LEAD	POUND	0.	2.
ATMOS MERCURY	POUND	0.	0.
ATMOSPHERIC CHLORINE	POUNDS	0.	0.
WATERBORNE FLUORIDES	POUND	0.	0.
WATERBORNE DISS SOLIDS	POUND	77.	1057.
WATERBORNE BOD	POUND	10.	1904.
WATERBORNE PHENOL	POUND	0.	1.
WATERBORNE SULFIDES	POUND	0.	1.
WATERBORNE OIL	POUND	2.	38.
WATERBORNE COD	POUND	11.	6.
WATERBORNE SUSP SOLIDS	POUND	4.	2755.
WATERBORNE ACID	POUND	4.	150.
WATERBORNE METAL ION	POUND	1.	37.
WATERBORNE CHEMICALS	POUND	0.	0.
WATERBORNE CYANIDE	POUND	0.	0.
WATERBORNE ALKALINITY	POUND	0.	0.
WATERBORNE CHROMIUM	POUND	0.	0.
WATERBORNE IRON	POUND	0.	0.
WATERBORNE ALUMINUM	POUND	0.	0.
WATERBORNE NICKEL	POUND	0.	0.
WATERBORNE MERCURY	POUND	0.	0.
WATERBORNE LEAD	POUND	0.	0.

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TABLE 10 (Concluded)

SUMMARY OF SYSTEMS

NAME	UNITS	BOTTLE SYSTEM 16.0 TON	FILLING	PACKAGE	DISPOSAL	TRANS	STEEL CLOSURE 4000 LBS
SUMMARY OF ENVIRONMENTAL IMPACTS							
RAW MATERIALS	POUNDS	47863.	3261.	31228.	0.	0.	5743.
ENERGY	MIL BTU	347.	478.	492.	3.	200.	108.
WATER	THOU GAL	86.	421.	435.	0.	12.	107.
INDUSTRIAL SOLID WASTES	CUBIC FT	204.	47.	60.	0.	0.	203.
ATM EMMISSIONS	POUNDS	1421.	1572.	3068.	100.	1179.	387.
WATERBORNE WASTES	POUNDS	95.	1368.	969.	2.	101.	999.
POST-CONSUMER SOL WASTE	CUBIC FT	0.	0.	0.	642.	0.	0.
INDEX OF ENVIRONMENTAL IMPACTS							
NAME	STANDARD VALUES						
RAW MATERIALS	8791.	544	37	355	0	0	65
ENERGY	163.	214	294	303	2	123	66
WATER	106.	81	398	411	0	11	101
INDUSTRIAL SOLID WASTES	51.	396	92	116	0	1	396
ATM EMMISSIONS	771.	184	204	398	13	153	50
WATERBORNE WASTES	353.	27	388	275	1	29	283
POST-CONSUMER SOL WASTE	67.	0	0	0	956	0	0
UNWEIGHTED INDEX		1446	1413	1858	972	317	961
WEIGHTED INDEX OF ENVIRONMENTAL IMPACTS							
NAME	WEIGHT						
RAW MATERIALS	.05	27	2	18	0	0	3
ENERGY	.40	85	118	121	1	49	27
WATER	.05	4	20	21	0	1	5
INDUSTRIAL SOLID WASTES	.05	20	5	6	0	0	20
ATM EMMISSIONS	.20	37	41	80	3	31	10
WATERBORNE WASTES	.20	5	78	55	0	6	57
POST-CONSUMER SOL WASTE	.05	0	0	0	48	0	0
WEIGHTED COMPOSITE INDEX		178	264	301	52	87	122

TABLE 11

IMPACTS FOR 1 MILLION PLASTIC COATED GLASS BOTTLES

INPUT TO SYSTEMS

MATERIALS

NAME	UNITS	BOTTLE SYSTEM 16.0 TON	FILLING	PACKAGE	DISPOSAL	TRANS	STEEL CLOSURE 4000 LBS
MATERIAL WOOD FIBER	POUNDS	0.	0.	29169.	0.	0.	0.
MATERIAL LIMESTONE	POUND	13848.	0.	0.	0.	0.	1649.
MATERIAL IRON ORE	POUND	0.	0.	0.	0.	0.	3816.
MATERIAL SALT	POUND	7339.	3213.	0.	0.	0.	0.
MATERIAL GLASS SAND	POUND	21120.	0.	0.	0.	0.	0.
MATERIAL NAT SODA ASH	POUND	2480.	0.	0.	0.	0.	0.
MATERIAL FELDSPAR	POUND	2416.	0.	0.	0.	0.	0.
MATERIAL BAUXITE ORE	POUND	0.	0.	0.	0.	0.	0.
MATERIAL PROCESS ADD	POUNDS	660.	48.	2059.	0.	0.	278.
ENERGY PROCESS	MIL BTU	343.	478.	442.	0.	0.	105.
ENERGY TRANSPORT	MIL BTU	5.	0.	50.	3.	200.	2.
ENERGY OF MATL RESOURCE	MIL BTU	0.	0.	0.	0.	0.	1.
WATER VOLUME	THOU GAL	86.	421.	435.	0.	12.	107.

OUTPUT FROM SYSTEMS

MATERIALS

NAME	UNITS	BOTTLE SYSTEM 16.0 TON	FILLING	PACKAGE	DISPOSAL	TRANS	STEEL CLOSURE 4000 LBS
SOLID WASTES PROCESS	POUND	8417.	2036.	1353.	0.	0.	1636.
SOLID WASTES FUEL COMB	POUND	263.	272.	1861.	1.	32.	97.
SOLID WASTES MINING	POUND	6396.	1188.	1206.	0.	0.	13317.
SOLID WASTE POST-CONSUM	CUBIC FT	0.	0.	0.	642.	0.	0.
ATMOS PARTICULATES	POUND	311.	105.	883.	0.	34.	107.
ATMOS NITROGEN OXIDES	POUND	403.	506.	390.	5.	359.	63.
ATMOS HYDROCARBONS	POUND	292.	373.	176.	8.	180.	89.
ATMOS SULFUR OXIDES	POUND	277.	434.	1209.	1.	92.	86.
ATMOS CARBON MONOXIDE	POUND	120.	137.	168.	77.	498.	27.
ATMOS ALDEHYDES	POUND	1.	2.	3.	0.	8.	0.
ATMOS OTHER ORGANICS	POUND	1.	2.	2.	9.	7.	0.
ATMOS ODOROUS SULFUR	POUND	0.	0.	237.	0.	0.	4.
ATMOS AMMONIA	POUND	16.	0.	0.	0.	1.	11.
ATMOS HYDROGEN FLOURIDE	POUND	0.	0.	0.	0.	0.	0.
ATMOS LEAD	POUND	0.	0.	0.	0.	1.	0.
ATMOS MERCURY	POUND	0.	0.	0.	0.	0.	0.
ATMOSPHERIC CHLORINE	POUNDS	0.	13.	0.	0.	0.	0.
WATERBORNE FLUORIDES	POUND	0.	0.	0.	0.	0.	0.
WATERBORNE DISS SOLIDS	POUND	55.	97.	74.	2.	99.	9.
WATERBORNE BOD	POUND	0.	1000.	596.	0.	0.	0.
WATERBORNE PHENOL	POUND	0.	0.	0.	0.	0.	0.
WATERBORNE SULFIDES	POUND	0.	0.	0.	0.	0.	0.
WATERBORNE OIL	POUND	3.	0.	0.	0.	0.	2.
WATERBORNE COD	POUND	0.	0.	1.	0.	1.	0.
WATERBORNE SUSP SOLIDS	POUND	26.	260.	282.	0.	1.	965.
WATERBORNE ACID	POUND	8.	8.	13.	0.	0.	18.
WATERBORNE METAL ION	POUND	2.	2.	3.	0.	0.	5.
WATERBORNE CHEMICALS	POUND	0.	0.	0.	0.	0.	0.
WATERBORNE CYANIDE	POUND	0.	0.	0.	0.	0.	0.
WATERBORNE ALKALINITY	POUND	0.	0.	0.	0.	0.	0.
WATERBORNE CHROMIUM	POUND	0.	0.	0.	0.	0.	0.
WATERBORNE IRON	POUND	0.	0.	0.	0.	0.	0.
WATERBORNE ALUMINUM	POUND	0.	0.	0.	0.	0.	0.
WATERBORNE NICKEL	POUND	0.	0.	0.	0.	0.	0.
WATERBORNE MERCURY	POUND	0.	0.	0.	0.	0.	0.
WATERBORNE LEAD	POUND	0.	0.	0.	0.	0.	0.

TABLE 11 (Concluded)

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                                                       SUMMARY OF SYSTEMS

                                                                  POLYSTY              GLASS
                                                                  FOAM                 SYSTEM
                                                                  JACKET               FILLING
                                                                  4400 LBS             ETC.
SUMMARY OF ENVIRONMENTAL IMPACTS
        NAME                           UNITS


        RAW MATERIALS               POUNDS                             22.              617172.
        ENERGY                      MIL BTU                           286.                6081.
        WATER                       THOU GAL                           39.                3235.
        INDUSTRIAL SOLID WASTES     CUBIC FT                           12.                2678.
        ATM EMMISSIONS              POUNDS                           1040.               27740.
        WATERBORNE WASTES           POUNDS                            109.                5949.
        POST-CONSUMER SOL WASTE     CUBIC FT                            0.                3484.

INDEX OF ENVIRONMENTAL IMPACTS
        NAME                          STANDARD
                                       VALUES


        RAW MATERIALS                  61719.                            0                 1000
        ENERGY                           637.                           45                  955
        WATER                            327.                           12                  988
        INDUSTRIAL SOLID WASTES          269.                            5                  995
        ATM EMMISSIONS                  2878.                           36                  964
        WATERBORNE WASTES                606.                           18                  982
        POST-CONSUMER SOL WASTE          348.                            0                 1000

        UNWEIGHTED INDEX                                               116                 6884

WEIGHTED INDEX OF ENVIRONMENTAL IMPACTS
        NAME                           WEIGHT


        RAW MATERIALS                    .05                             0                   50
        ENERGY                           .40                            18                  382
        WATER                            .05                             1                   49
        INDUSTRIAL SOLID WASTES          .05                             0                   50
        ATM EMMISSIONS                   .20                             7                  193
        WATERBORNE WASTES                .20                             4                  196
        POST-CONSUMER SOL WASTE          .05                             0                   50

        WEIGHTED COMPOSITE INDEX                                        30                  970
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TABLE 12

IMPACTS FOR 1 MILLION SOFT DRINK CONTAINERS

INPUT TO SYSTEMS

MATERIALS

NAME	UNITS	15 RET	ABS	ALSTL	PCG	CSTL	OWG	ALUM
MATERIAL WOOD FIBER	POUNDS	10162.	45274.	2928.	56746.	2703.	62627.	2699.
MATERIAL LIMESTONE	POUND	23287.	1649.	53682.	183404.	43021.	224431.	10752.
MATERIAL IRON ORE	POUND	3816.	3816.	124200.	3816.	91742.	3820.	0.
MATERIAL SALT	POUND	14145.	0.	0.	96327.	3335.	118069.	10892.
MATERIAL GLASS SAND	POUND	33000.	0.	0.	277200.	0.	339768.	0.
MATERIAL NAT SODA ASH	POUND	3875.	0.	0.	32550.	0.	39897.	0.
MATERIAL FELDSPAR	POUND	3775.	0.	0.	31710.	0.	38867.	0.
MATERIAL BAUXITE ORE	POUND	0.	0.	0.	0.	5957.	0.	19286.
MATERIAL PROCESS ADD	POUNDS	2639.	5587.	9481.	12982.	10590.	15331.	10571.
ENERGY PROCESS	MIL BTU	1433.	3475.	3520.	6111.	4770.	7032.	7594.
ENERGY TRANSPORT	MIL BTU	217.	986.	231.	461.	276.	518.	261.
ENERGY OF MATL RESOURCE	MIL BTU	1.	1921.	55.	108.	276.	1.	618.
WATER VOLUME	THOU GAL	1000.	2995.	3545.	2661.	3187.	2961.	1547.

OUTPUT FROM SYSTEMS

MATERIALS

NAME	UNITS	15 RET	ABS	ALSTL	PCG	CSTL	OWG	ALUM
SOLID WASTES PROCESS	POUND	16055.	5819.	56508.	116813.	46459.	141701.	15303.
SOLID WASTES FUEL COMB	POUND	2829.	8767.	3451.	8647.	9141.	9541.	22428.
SOLID WASTES MINING	POUND	25927.	23393.	433680.	101404.	370453.	120218.	161777.
SOLID WASTE POST-CONSUM	CUBIC FT	821.	2018.	327.	3488.	302.	3425.	298.
ATMOS PARTICULATES	POUND	1369.	2317.	3634.	6266.	4039.	7341.	4523.
ATMOS NITROGEN OXIDES	POUND	1802.	8541.	2546.	7429.	4204.	8485.	8092.
ATMOS HYDROCARBONS	POUND	1338.	6633.	3588.	5483.	4723.	5905.	5962.
ATMOS SULFUR OXIDES	POUND	1547.	4355.	3040.	6238.	5971.	7178.	12583.
ATMOS CARBON MONOXIDE	POUND	1672.	4312.	1679.	3683.	2805.	4082.	4620.
ATMOS ALDEHYDES	POUND	17.	31.	17.	37.	24.	42.	32.
ATMOS OTHER ORGANICS	POUND	20.	60.	13.	50.	19.	55.	30.
ATMOS ODOROUS SULFUR	POUND	186.	439.	162.	532.	124.	579.	22.
ATMOS AMMONIA	POUND	36.	51.	346.	217.	257.	264.	3.
ATMOS HYDROGEN FLOURIDE	POUND	0.	0.	0.	0.	19.	0.	62.
ATMOS LEAD	POUND	3.	3.	2.	3.	2.	3.	2.
ATMOS MERCURY	POUND	0.	0.	0.	0.	0.	0.	0.
ATMOSPHERIC CHLORINE	POUNDS	11.	0.	0.	0.	13.	0.	43.
WATERBORNE FLUORIDES	POUND	0.	0.	0.	0.	79.	0.	256.
WATERBORNE DISS SOLIDS	POUND	298.	1143.	390.	1168.	699.	1286.	1260.
WATERBORNE BOD	POUND	520.	1426.	74.	1282.	111.	1391.	202.
WATERBORNE PHENOL	POUND	0.	0.	0.	1.	1.	1.	2.
WATERBORNE SULFIDES	POUND	0.	1.	0.	1.	1.	1.	1.
WATERBORNE OIL	POUND	7.	124.	75.	47.	175.	54.	385.
WATERBORNE COD	POUND	2.	994.	14.	16.	463.	6.	1465.
WATERBORNE SUSP SOLIDS	POUND	1560.	2055.	31429.	2213.	27510.	2341.	13731.
WATERBORNE ACID	POUND	53.	121.	591.	160.	541.	181.	359.
WATERBORNE METAL ION	POUND	13.	30.	148.	40.	1728.	45.	5247.
WATERBORNE CHEMICALS	POUND	0.	9.	4.	0.	152.	0.	481.
WATERBORNE CYANIDE	POUND	0.	0.	0.	0.	0.	0.	0.
WATERBORNE ALKALINITY	POUND	1000.	0.	0.	0.	0.	0.	0.
WATERBORNE CHROMIUM	POUND	0.	0.	0.	0.	0.	0.	0.
WATERBORNE IRON	POUND	0.	1.	0.	0.	0.	0.	0.
WATERBORNE ALUMINUM	POUND	0.	1.	0.	0.	0.	0.	0.
WATERBORNE NICKEL	POUND	0.	1.	0.	0.	0.	0.	0.
WATERBORNE MERCURY	POUND	0.	0.	0.	0.	0.	0.	0.
WATERBORNE LEAD	POUND	0.	0.	0.	0.	0.	0.	0.

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TABLE 12 (Concluded)

SUMMARY OF SYSTEMS

SUMMARY OF ENVIRONMENTAL IMPACTS

NAME	UNITS	15 RET	ABS	ALSTL	PCG	CSTL	OWG	ALUM
RAW MATERIALS	POUNDS	102699.	56326.	190291.	694736.	157349.	842810.	54200.
ENERGY	MIL BTU	1651.	6383.	3806.	6681.	5322.	7550.	8464.
WATER	THOU GAL	1000.	2995.	3545.	2661.	3107.	2961.	1547.
INDUSTRIAL SOLID WASTES	CUBIC FT	605.	513.	6654.	3063.	5752.	3665.	2693.
ATM EMMISSIONS	POUNDS	8001.	26743.	15027.	29939.	22202.	33934.	35973.
WATERBORNE WASTES	POUNDS	3463.	5907.	32726.	4924.	31460.	5306.	23390.
POST-CONSUMER SOL WASTE	CUBIC FT	821.	2018.	327.	3488.	302.	3425.	298.

INDEX OF ENVIRONMENTAL IMPACTS

NAME	STANDARD VALUES	15 RET	ABS	ALSTL	PCG	CSTL	OWG	ALUM
RAW MATERIALS	299773.	34	19	63	232	52	281	18
ENERGY	5694.	29	112	67	117	93	133	149
WATER	2545.	39	118	139	105	122	116	61
INDUSTRIAL SOLID WASTES	3279.	18	16	203	93	175	112	82
ATM EMMISSIONS	24545.	33	109	61	122	90	138	147
WATERBORNE WASTES	15311.	23	39	214	32	205	35	153
POST-CONSUMER SOL WASTE	1525.	54	132	21	229	20	224	28
UNWEIGHTED INDEX		230	545	768	930	757	1039	638

WEIGHTED INDEX OF ENVIRONMENTAL IMPACTS

NAME	WEIGHT	15 RET	ABS	ALSTL	PCG	CSTL	OWG	ALUM
RAW MATERIALS	.05	2	1	3	12	3	14	1
ENERGY	.40	12	45	27	47	37	53	59
WATER	.05	2	6	7	5	6	6	3
INDUSTRIAL SOLID WASTES	.05	1	1	10	5	9	6	4
ATM EMMISSIONS	.20	7	22	12	24	18	28	29
WATERBORNE WASTES	.20	5	8	43	6	41	7	31
POST-CONSUMER SOL WASTE	.05	3	7	1	11	1	11	1
WEIGHTED COMPOSITE INDEX		32	90	103	110	115	125	128

TABLE 13

IMPACTS FOR 1 MILLION BEER CONTAINERS

INPUT TO SYSTEMS

MATERIALS

NAME	UNITS	19 TRIP	10 TRIP	5 TRIP	ABS	ALL STL	PLASTSHD	OWG	BIMETAL	ALUM
MATERIAL WOOD FIBER	POUNDS	28992.	41110.	120339.	77267.	2920.	82101.	88041.	2703.	2699.
MATERIAL LIMESTONE	POUND	15497.	28047.	54445.	1649.	53682.	153112.	177303.	63021.	10752.
MATERIAL IRON ORE	POUND	3816.	3816.	3816.	3816.	124200.	3816.	3816.	91742.	0.
MATERIAL SALT	POUND	10552.	17203.	31194.	0.	0.	40272.	93093.	3335.	10892.
MATERIAL GLASS SAND	POUND	21120.	40260.	80520.	0.	0.	231400.	267894.	0.	0.
MATERIAL NAT SODA ASH	POUND	2480.	4727.	9455.	0.	0.	27125.	31457.	0.	0.
MATERIAL FELDSPAR	POUND	2416.	4605.	9211.	0.	0.	26425.	30645.	0.	0.
MATERIAL BAUXITE ORE	POUND	0.	0.	0.	0.	0.	0.	0.	5957.	19280.
MATERIAL PROCESS ADD	POUNDS	3032.	4491.	11354.	7861.	9483.	13343.	14752.	10592.	10573.
ENERGY PROCESS.	MIL BTU	1366.	1917.	3891.	3961.	3631.	5736.	6218.	4878.	7703.
ENERGY TRANSPORT	MIL BTU	259.	301.	481.	961.	180.	523.	559.	226.	210.
ENERGY OF MATL RESOURCE	MIL BTU	1.	1.	1.	1921.	55.	108.	1.	276.	610.
WATER VOLUME	THOU GAL	1060.	1440.	3042.	3411.	3544.	3274.	3450.	3180.	1546.

OUTPUT FROM SYSTEMS

MATERIALS

NAME	UNITS	19 TRIP	10 TRIP	5 TRIP	ABS	ALL STL	PLASTSHD	OWG	BIMETAL	ALUM
SOLID WASTES PROCESS	POUND	13434.	21922.	42265.	9154.	56508.	101373.	115977.	46459.	15303.
SOLID WASTES FUEL COMB	POUND	2513.	3710.	9656.	10732.	3464.	9595.	10066.	9154.	22441.
SOLID WASTES MINING	POUND	22100.	28533.	44284.	24593.	434094.	88313.	99285.	370858.	162186.
SOLID WASTE POST-CONSUM	CUBIC FT	672.	1121.	2708.	2536.	327.	3484.	3841.	302.	298.
ATMOS PARTICULATES	POUND	1435.	2168.	5335.	3510.	3693.	6570.	7219.	4097.	4581.
ATMOS NITROGEN OXIDES	POUND	1724.	2321.	4300.	8747.	2561.	6888.	7407.	4219.	8107.
ATMOS HYDROCARBONS	POUND	1117.	1494.	2617.	6586.	3534.	4853.	4908.	4671.	5909.
ATMOS SULFUR OXIDES	POUND	2091.	2682.	6154.	5045.	3205.	6123.	6636.	6132.	12745.
ATMOS CARBON MONOXIDE	POUND	1030.	1309.	2286.	3891.	1240.	3253.	3491.	2376.	4186.
ATMOS ALDEHYDES	POUND	14.	17.	29.	28.	13.	36.	39.	20.	28.
ATMOS OTHER ORGANICS	POUND	22.	30.	63.	69.	12.	57.	60.	18.	29.
ATMOS ODOROUS SULFUR	POUND	239.	364.	1061.	773.	162.	808.	840.	124.	22.
ATMOS AMMONIA	POUND	27.	42.	72.	52.	346.	183.	211.	257.	3.
ATMOS HYDROGEN FLOURIDE	POUND	0.	0.	0.	0.	0.	0.	0.	19.	62.
ATMOS LEAD	POUND	1.	1.	2.	2.	0.	2.	2.	[illegible]	0.
ATMOS MERCURY	POUND	0.	0.	0.	0.	0.	0.	0.	0.	0.
ATMOSPHERIC CHLORINE	POUNDS	13.	13.	13.	0.	0.	0.	0.	13.	43.
WATERBORNE FLUORIDES	POUND	0.	0.	0.	0.	0.	0.	0.	79.	256.
WATERBORNE DISS SOLIDS	POUND	336.	433.	775.	1195.	384.	1133.	1175.	693.	1254.
WATERBORNE BOD	POUND	1593.	1883.	3592.	2202.	74.	1914.	1986.	111.	202.
WATERBORNE PHENOL	POUND	0.	0.	1.	0.	0.	1.	1.	1.	2.
WATERBORNE SULFIDES	POUND	0.	0.	1.	1.	0.	1.	1.	1.	1.
WATERBORNE OIL	POUND	6.	9.	15.	124.	75.	40.	44.	175.	385.
WATERBORNE COD	POUND	2.	3.	5.	995.	14.	17.	6.	463.	1465.
WATERBORNE SUSP SOLIDS	POUND	1533.	1808.	2905.	2747.	31429.	2759.	2843.	27510.	13731.
WATERBORNE ACID	POUND	44.	60.	112.	134.	595.	154.	165.	545.	363.
WATERBORNE METAL ION	POUND	17.	15.	28.	34.	149.	34.	41.	1729.	5248.
WATERBORNE CHEMICALS	POUND	0.	0.	0.	9.	4.	0.	0.	152.	481.
WATERBORNE CYANIDE	POUND	0.	0.	0.	0.	0.	0.	0.	0.	0.
WATERBORNE ALKALINITY	POUND	0.	0.	0.	0.	0.	0.	0.	0.	0.
WATERBORNE CHROMIUM	POUND	0.	0.	0.	0.	0.	0.	0.	0.	0.
WATERBORNE IRON	POUND	0.	0.	0.	1.	0.	0.	0.	0.	0.
WATERBORNE ALUMINUM	POUND	0.	0.	0.	1.	0.	0.	0.	0.	0.
WATERBORNE NICKEL	POUND	0.	0.	0.	1.	0.	0.	0.	0.	0.
WATERBORNE MERCURY	POUND	0.	0.	0.	0.	0.	0.	0.	0.	0.
WATERBORNE LEAD	POUND	0.	0.	0.	0.	0.	0.	0.	0.	0.

TABLE 13 (Concluded)

SUMMARY OF SYSTEMS

SUMMARY OF ENVIRONMENTAL IMPACTS

NAME	UNITS	19 TRIP	10 TRIP	5 TRIP	ABS	ALL STL	PLASTSHD	OWG	BIMETAL	ALUM
RAW MATERIALS	POUNDS	87906.	144261.	320333.	90593.	190293.	617194.	705004.	157351.	54282.
ENERGY	MIL BTU	1626.	2219.	4373.	6843.	3866.	6367.	6778.	5380.	8523.
WATER	THOU GAL	1060.	1440.	3042.	3911.	3544.	3274.	3450.	3106.	1546.
INDUSTRIAL SOLID WASTES	CUBIC FT	514.	731.	1299.	600.	6670.	2690.	3042.	5757.	2699.
ATM EMMISSIONS	POUNDS	7713.	10440.	21931.	28701.	14767.	28781.	30813.	21948.	35716.
WATERBORNE WASTES	POUNDS	3528.	4211.	7434.	7443.	32724.	6058.	6261.	31458.	23388.
POST-CONSUMER SOL WASTE	CUBIC FT	672.	1121.	2708.	2536.	327.	3484.	3841.	302.	298.

INDEX OF ENVIRONMENTAL IMPACTS

NAME	STANDARD VALUES	19 TRIP	10 TRIP	5 TRIP	ABS	ALL STL	PLASTSHD	OWG	BIMETAL	ALUM
RAW MATERIALS	263015.	33	55	122	34	72	235	268	60	21
ENERGY	5108.	32	43	86	134	76	125	133	105	167
WATER	2708.	39	53	112	144	131	121	127	115	57
INDUSTRIAL SOLID WASTES	2667.	19	27	49	23	250	101	114	216	101
ATM EMMISSIONS	22312.	35	47	98	129	66	129	138	98	160
WATERBORNE WASTES	13612.	26	31	55	55	240	45	46	231	172
POST-CONSUMER SOL WASTE	1699.	40	66	159	149	19	205	226	18	18
UNWEIGHTED INDEX		224	322	681	668	854	961	1052	843	696

WEIGHTED INDEX OF ENVIRONMENTAL IMPACTS

NAME	WEIGHT	19 TRIP	10 TRIP	5 TRIP	ABS	ALL STL	PLASTSHD	OWG	BIMETAL	ALUM
RAW MATERIALS	.05	2	3	6	2	4	12	13	3	1
ENERGY	.40	13	17	34	54	30	50	53	42	67
WATER	.05	2	3	6	7	7	6	6	6	3
INDUSTRIAL SOLID WASTES	.05	1	1	2	1	13	5	6	11	5
ATM EMMISSIONS	.20	7	9	20	26	13	26	28	20	32
WATERBORNE WASTES	.20	5	6	11	11	48	9	9	46	34
POST-CONSUMER SOL WASTE	.05	2	3	8	7	1	10	11	1	1
WEIGHTED COMPOSITE INDEX		32	42	87	108	116	118	126	129	143

TABLE 14

IMPACTS FOR 1 TON OF EACH PROCESS IN THE GLASS SYSTEM

INPUT TO SYSTEMS

MATERIALS NAME	UNITS	GLASS SAND MINING	LIMESTON MINING	LIME MFG	SODA ASH MINING	SALT MINING (BRINE)	SODA ASH MANUF	FELDSPAR MINING	STEEL CLOSURE	SEPARATE CULLET
MATERIAL WOOD FIBER	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL LIMESTONE	POUNDS	0.000	0.000	4000.000	0.000	0.000	2500.000	0.000	[illegible]	0.000
MATERIAL IRON ORE	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1926.000	0.000
MATERIAL SALT	POUNDS	0.000	0.000	0.000	0.000	0.000	3300.000	0.000	0.000	0.000
MATERIAL GLASS SAND	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUNDS	0.000	0.030	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUNDS	0.000	0.060	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUNDS	0.000	0.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	138.972	0.000
ENERGY PROCESS	MIL BTU	.026	.043	5.100	.638	.236	13.545	.797	52.576	12.103
ENERGY TRANSPORT	MIL BTU	.044	.032	.036	0.000	.020	0.000	.624	.870	.252
ENERGY OF MATL RESOURCE	MIL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.501	0.000
WATER VOLUME	THOU GAL	1.015	.094	.322	1.289	1.004	16.502	4.547	53.773	.461

MATERIALS NAME	UNITS	GLASS CONTAIN FAB	POLYSTY FOAM JACKET	PACKAGE CORRUG	PACKAGE BLEACHED KRAFT	FILLING RETURNAB BEER BOTTLE	FILLING ONE WAY BEER	DISPOSAL	FILLING RETURN SOFT DRINK	FILLING ONE WAY SOFT DRINK
MATERIAL WOOD FIBER	POUNDS	0.000	0.000	1991.720	2037.000	0.000	0.000	0.000	0.000	110.734
MATERIAL LIMESTONE	POUNDS	336.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL IRON ORE	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUNDS	0.000	0.000	0.000	0.000	15.744	0.000	0.000	10.174	0.000
MATERIAL GLASS SAND	POUNDS	1320.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUNDS	155.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUNDS	151.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	46.000	10.000	140.587	144.040	.236	0.000	0.000	.152	7.071
ENERGY PROCESS	MIL BTU	14.510	81.240	30.214	41.275	2.341	.769	0.000	1.677	3.458
ENERGY TRANSPORT	MIL BTU	.149	0.000	3.303	3.044	.000	0.000	.113	.000	.637
ENERGY OF MATL RESOURCE	MIL BTU	0.000	[illegible]	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATER VOLUME	THOU GAL	1.104	17.643	29.720	42.422	2.064	1.404	.007	1.198	3.652

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TABLE 14 (Continued)

OUTPUT FROM SYSTEMS

MATERIALS NAME	UNITS	GLASS SAND MINING	LIMESTON MINING	LIME MFG	SODA ASH MINING	SALT MINING (BRINE)	SODA ASH MANUF	FELDSPAR MINING	STEEL CLOSURE	SEPARATE CULLET
SOLID WASTES PROCESS	POUND	0.000	0.000	365.000	0.000	0.000	3340.000	0.000	[illegible]	[illegible]
SOLID WASTES FUEL COMB	POUND	.010	.121	1.648	0.000	.052	.401	3.345	[illegible]	[illegible]
SOLID WASTES MINING	POUND	3.613	.220	36.636	120.000	.074	131.100	4604.872	[illegible]	[illegible]
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	[illegible]
ATMOS PARTICULATES	POUND	.427	13.023	40.272	10.012	.032	40.052	15.404	[illegible]	[illegible]
ATMOS NITROGEN OXIDES	POUND	1.197	.135	5.214	.016	.318	10.021	2.754	[illegible]	[illegible]
ATMOS HYDROCARBONS	POUND	.753	.053	2.786	.691	.273	3.169	.729	[illegible]	[illegible]
ATMOS SULFUR OXIDES	POUND	1.121	.006	11.272	.019	.048	44.520	1.038	[illegible]	[illegible]
ATMOS CARBON MONOXIDE	POUND	.481	.114	1.765	.240	.111	3.497	1.476	[illegible]	[illegible]
ATMOS ALDEHYDES	POUND	.004	.001	.009	.001	.002	.053	.019	[illegible]	[illegible]
ATMOS OTHER ORGANICS	POUND	.004	.001	.014	.002	.001	.020	.016	.100	[illegible]
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	[illegible]	[illegible]
ATMOS AMMONIA	POUND	.000	.000	.000	0.000	.000	7.007	.002	[illegible]	[illegible]
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	[illegible]
ATMOS LEAD	POUND	.000	.000	.000	0.000	.000	.000	.001	.000	.002
ATMOS MERCURY	POUND	.000	.000	.000	0.000	.000	.001	.000	[illegible]	[illegible]
ATMOSPHERIC CHLORINE	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	[illegible]	[illegible]
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	.144	.020	.466	.106	.047	1.516	.364	[illegible]	[illegible]
WATERBORNE BOD	POUND	.000	.000	.000	0.000	.000	.003	.001	.007	[illegible]
WATERBORNE PHENOL	POUND	.000	.000	.000	0.000	.000	.006	.000	[illegible]	[illegible]
WATERBORNE SULFIDES	POUND	.000	.000	.000	0.000	.000	.002	.000	[illegible]	[illegible]
WATERBORNE OIL	POUND	.000	.000	.000	0.000	.000	.002	.000	[illegible]	[illegible]
WATERBORNE COD	POUND	.001	.000	.001	0.000	.000	.013	.004	[illegible]	[illegible]
WATERBORNE SUSP SOLIDS	POUND	1.000	.000	.001	0.000	.000	7.008	.002	[illegible]	[illegible]
WATERBORNE ACID	POUND	.036	.002	.305	0.000	.001	1.303	.050	[illegible]	[illegible]
WATERBORNE METAL ION	POUND	.009	.001	.096	0.000	.000	.346	.013	[illegible]	[illegible]
WATERBORNE CHEMICALS	POUND	0.000	0.000	0.000	0.000	0.000	.006	0.000	[illegible]	0.000
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	.001	0.000	0.003	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE LEAD	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

MATERIALS NAME	UNITS	GLASS CONTAIN FAB	POLYSTY FOAM JACKET	PACKAGE CORRUG	PACKAGE BLEACHED KRAFT	FILLING RETURNAB BEER BOTTLE	FILLING ONE WAY BEER	DISPOSAL	FILLING RETURN SOFT DRINK	FILLING ONE WAY SOFT DRINK
SOLID WASTES PROCESS	POUND	45.000	136.000	92.411	144.690	4.977	9.800	0.000	.114	11.280
SOLID WASTES FUEL COMB	POUND	15.615	113.746	127.053	163.530	1.332	.586	.019	1.342	[illegible]
SOLID WASTES MINING	POUND	22.881	170.646	82.367	108.774	5.021	2.715	0.000	6.606	9.966
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	11.800	0.000	11.014
ATMOS PARTICULATES	POUND	3.940	17.242	60.288	76.401	.513	.360	.014	.356	4.441
ATMOS NITROGEN OXIDES	POUND	22.270	124.674	26.661	34.763	2.481	.760	.158	1.463	1.926
ATMOS HYDROCARBONS	POUND	16.987	229.726	12.009	16.285	1.027	.512	.270	1.241	2.877
ATMOS SULFUR OXIDES	POUND	4.667	63.310	82.563	53.903	2.126	1.086	.029	1.642	4.344
ATMOS CARBON MONOXIDE	POUND	6.437	38.538	11.463	14.067	.473	.219	1.008	.507	4.868
ATMOS ALDEHYDES	POUND	.044	.176	.194	.246	.010	.003	.010	.061	.091
ATMOS OTHER ORGANICS	POUND	.088	.226	.144	.177	.008	.002	.004	.005	.046
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	16.161	21.266	0.000	0.000	0.000	0.000	1.195
ATMOS AMMONIA	POUND	.007	0.000	.020	.027	.001	.000	.000	.090	.091
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.060
ATMOS LEAD	POUND	.000	0.000	.005	.006	.000	.000	.002	.008	.008
ATMOS MERCURY	POUND	.000	.001	.001	.001	.000	.000	0.000	.000	.000
ATMOSPHERIC CHLORINE	POUNDS	0.000	0.000	0.000	0.030	.062	0.000	0.000	.040	0.000
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	3.081	36.967	5.075	6.836	.474	.128	.060	.205	.710
WATERBORNE BOD	POUND	.002	4.406	40.706	49.478	4.901	.000	.000	.140	2.887
WATERBORNE PHENOL	POUND	.001	.002	.004	.005	.000	.000	.000	.008	.001
WATERBORNE SULFIDES	POUND	.001	.002	.005	.006	.000	.000	.000	.010	.001
WATERBORNE OIL	POUND	.291	1.002	.005	.007	.000	.000	.000	.009	.001
WATERBORNE COD	POUND	.008	5.018	.043	.057	.002	.001	.001	.001	.006
WATERBORNE SUSP SOLIDS	POUND	.005	2.011	14.277	44.093	1.276	.000	.000	.160	2.390
WATERBORNE ACID	POUND	.231	1.730	.866	1.144	.039	.029	.000	.051	.166
WATERBORNE METAL ION	POUND	.058	.032	.216	.286	.010	.007	.000	.013	.026
WATERBORNE CHEMICALS	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	[illegible]	0.000
WATERBORNE CHROMIUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	0.000	0.000	.000	0.000	0.000	.000	0.000
WATERBORNE LEAD	POUND	0.000	0.000	0.000	0.000	.000	0.000	0.000	.000	0.000

TABLE 14 (Concluded)

SUMMARY OF SYSTEMS

		GLASS SAND MINING	LIMESTON MINING	LIME MFG	SODA ASH MINING	SALT MINING (BRINE)	SODA ASH MANUF	FELDSPAR MINING	STEEL CLOSURE	SEPARATE CULLET
SUMMARY OF ENVIRONMENTAL IMPACTS NAME	UNITS									
RAW MATERIALS	POUNDS	0.000	0.000	4000.000	0.000	0.000	5809.000	0.000	2871.662	0.000
ENERGY	MIL BTU	.983	.075	5.135	.638	.256	13.545	1.421	53.965	12.355
WATER	THOU GAL	1.815	.094	.322	1.209	1.004	16.502	4.547	53.723	.461
INDUSTRIAL SOLID WASTES	CUBIC FT	.057	.005	5.444	1.620	.002	46.865	62.211	101.583	.747
ATM EMMISSIONS	POUNDS	3.988	13.413	61.333	11.773	.786	109.948	22.240	193.625	44.766
WATERBORNE WASTES	POUNDS	1.190	.024	.949	.106	.048	10.286	.435	499.166	4.151
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-11.800
INDEX OF ENVIRONMENTAL IMPACTS NAME	STANDARD VALUES									
RAW MATERIALS	305.728	0	0	1308	0	0	1900	0	939	0
ENERGY	5.413	18	1	95	12	5	250	26	997	228
WATER	3.336	54	3	10	36	30	495	136	1611	14
INDUSTRIAL SOLID WASTES	4.477	1	0	122	36	0	1047	1390	2269	17
ATM EMMISSIONS	23.706	17	57	259	50	3	464	94	817	189
WATERBORNE WASTES	16.312	7	0	6	1	0	63	3	3061	25
POST-CONSUMER SOL WASTE	.188	0	0	0	0	0	0	0	0	-6270
UNWEIGHTED INDEX		97	61	1800	135	38	4219	1649	9694	-5797
WEIGHTED INDEX OF ENVIRONMENTAL IMPACTS NAME	WEIGHT									
RAW MATERIALS	.05	0	0	65	0	0	95	0	47	0
ENERGY	.40	7	1	38	5	2	100	11	399	91
WATER	.05	3	0	0	2	2	25	7	81	1
INDUSTRIAL SOLID WASTES	.05	0	0	6	2	0	52	69	113	1
ATM EMMISSIONS	.20	3	11	52	10	1	93	19	163	38
WATERBORNE WASTES	.20	1	0	1	0	0	13	1	612	5
POST-CONSUMER SOL WASTE	.05	0	0	0	0	0	0	0	0	-313
WEIGHTED COMPOSITE INDEX		14	12	162	19	5	378	107	1415	-177

		GLASS CONTAIN FAB	POLYSTY FOAM JACKET	PACKAGE CORRUG	PACKAGE BLEACHED KRAFT	FILLING RETURNAB BEER BOTTLE	FILLING ONE WAY BEER	DISPOSAL	FILLING RETURN SOFT DRINK	FILLING ONE WAY SOFT DRINK
SUMMARY OF ENVIRONMENTAL IMPACTS NAME	UNITS									
RAW MATERIALS	POUNDS	2000.000	10.000	2132.315	2182.648	15.979	0.000	0.000	10.327	118.605
ENERGY	MIL BTU	18.699	130.040	33.597	45.138	2.341	.769	.113	1.677	4.115
WATER	THOU GAL	1.168	17.693	29.720	52.422	2.064	1.484	.007	1.198	3.652
INDUSTRIAL SOLID WASTES	CUBIC FT	1.124	5.677	4.075	5.683	.231	.177	.000	.136	.452
ATM EMMISSIONS	POUNDS	59.459	472.844	209.449	217.321	7.701	2.961	1.495	5.726	21.609
WATERBORNE WASTES	POUNDS	3.589	49.568	66.195	101.862	6.702	.165	.062	5.211	5.959
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	11.800	0.000	11.016
INDEX OF ENVIRONMENTAL IMPACTS NAME	STANDARD VALUES									
RAW MATERIALS	305.728	654	3	697	714	5	0	0	3	39
ENERGY	5.413	345	2403	621	834	43	14	2	31	76
WATER	3.336	35	531	891	1572	62	45	0	36	110
INDUSTRIAL SOLID WASTES	4.477	25	127	91	127	5	4	0	3	10
ATM EMMISSIONS	23.706	251	1995	884	917	32	12	6	24	91
WATERBORNE WASTES	16.312	22	304	406	624	41	1	0	32	37
POST-CONSUMER SOL WASTE	.188	0	0	0	0	0	0	6270	0	5853
UNWEIGHTED INDEX		1332	5363	3590	4788	188	76	6278	129	6215
WEIGHTED INDEX OF ENVIRONMENTAL IMPACTS NAME	WEIGHT									
RAW MATERIALS	.05	33	0	35	36	0	0	0	0	2
ENERGY	.40	138	961	248	334	17	6	1	12	30
WATER	.05	2	27	45	79	3	2	0	2	5
INDUSTRIAL SOLID WASTES	.05	1	6	5	6	0	0	0	0	1
ATM EMMISSIONS	.20	50	399	177	183	6	2	1	5	18
WATERBORNE WASTES	.20	4	61	81	125	8	0	0	6	7
POST-CONSUMER SOL WASTE	.05	0	0	0	0	0	0	313	0	293
WEIGHTED COMPOSITE INDEX		228	1454	591	763	34	10	315	25	356

Table 12 is a comparison of soft drink containers and Table 13 is the comparison of beer containers. This table is the basis for the discussions in Volume I. Finally, Table 14 shows the results of direct conversion of raw data contained in the remainder of this chapter into the appropriate impacts.

The composite indices in Table 7 verify the widely believed fact that reusable glass beverage containers produce less impact than single use containers of the same material. This is true even after the additional weight needed for structural integrity and additional processing and transportation is taken into account for returnable systems. The impacts of the one-way glass system range from 1.4 to 3.6 times as great as the returnable systems for the weighted values. The nonreturnable system produces more impacts in every category.

Table 8 shows the relative environmental impacts of the component processes of the one-way bottle system. It is interesting to note that two processes--paper packaging and glass manufacture--account for 67 percent of the weighted impacts. The glass plant alone accounts for 37 percent of the weighted impacts. Energy use is the most serious impact of the glass plant. Energy use in that one operation makes up 23 percent of the weighted impacts for the entire bottle system.

Tables 9 and 10 show the importance of component processes for returnable systems. Table 9 shows that impacts associated with the 5-trip returnable are concentrated in glass manufacturing and packaging, which accounts for 76 percent of the weighted impacts. The filling process steps, mainly bottle washing (including heating of the water) contribute 10 percent of the impacts. The processing impacts are water pollution from washing and energy.

For the 19-trip on-premise returnable, Table 10 shows the glass manufacturing is relatively less important, accounting for only 18 percent of the total weighted impacts. The filling is more important at 26 percent of the impacts, and closure impacts and transportation are also significant sources of environmental degradation. However, the largest single system impact is packaging, at 30 percent of the total.

Table 11 summarizes the impacts for plastic coated glass. The plastic used here is polystyrene, but other plastics have similar profiles. However, the amount of plastic required in the coating is so small it contributes only 3 percent of the system impact total. Thus, its advantage lies in the fact that less glass is required for PCG than for a conventional container.

Tables 12 and 13 are included here for reference. Table 12 is a comparison of soft drink containers and Table 13 is a comparison of beer containers. These tables are quite similar; and Table 13 is discussed in detail in Volume I. Table 14 converts the raw data found in the remainder of this chapter to environmental profiles. This table was discussed in Section A.

C. Glass Sand Mining

Glass sand is the predominant raw material for glass manufacture. It comprises 44 percent of the raw materials shown in Figure I and is the source of almost all of the silicon dioxide present in finished container glass. Silicon dioxide is the major chemical constituent of glass and amounts to approximately 70 percent by weight of finished container glass.

Glass sand is a high purity quartz sand which usually contains less than 1 percent of other materials. These stringent purity restrictions prevent the use of most of the sand available in this country. However, sizable deposits of glass sand do exist in New Jersey in the form of unconsolidated sand banks, and as sandstones found in the Alleghenies and the Mississippi Valley. In addition, there are smaller deposits located in various sections of the country.

The mining operations chosen depend on the nature of the deposit at each location. The mining operations range from simply scooping sand from a pit or bank and loading it into a truck to quarrying hard sandstone in a fashion similar to the procedures used to extract limestone. In the latter event, extensive crushing, washing and screening may be necessary.

Data pertaining to the mining of 1 ton of glass sand are shown in Table 15 along with the source of each number. The resulting impacts may be found in Summary Table 14. As shown by the composite index in Table 8, the overall environmental impact of mining sand is small as compared to other operations considered in glass manufacturing. Sand mining accounts for only 2 percent of total weighted impacts for OWG container manufacture.

TABLE 15

DATA FOR MINING OF 1 TON GLASS SAND

		Sources
Energy		89
Coal	0.0058 ton	
Distillate	0.31 gal.	
Residual	0.11 gal.	
Gas	431 cu ft	
Gasoline	0.076 gal.	
Electricity	13.9 kwhr	
Water volume, 1,800 gal.		90
Waterborne wastes		
Suspended solids--1 lb		67,78
Transportation		
Rail	90 ton-miles	84
Barge	3 ton-miles	86
Truck	27 ton-miles	67

D. Limestone Mining

Limestone is used by the glass industry as a source of calcium oxide in glass furnace operations. The limestone is heated in the furnace so that carbon dioxide is released, leaving calcium oxide behind. Calcium oxides act as a chemical stabilizer in the finished glass product.

Limestone is quarried primarily from open pits. The most economical method of recovering the stone has been blasting, followed by mechanical crushing and screening. According to the Bureau of Mines,[95] environmental problems plague these crushed stone producers more than any other mineral industry except sand and gravel. The reason for this is that limestone typically is mined quite close to the ultimate consumer, which frequently dictates that the mining operation be near, or even within, heavily populated areas. Hence, their environmental problems are accentuated by their high visibility.

The environmental consequences of limestone mining include: noise from heavy equipment and from blasting; dust from mining, crushing and screening; solid residues not properly disposed of; general unsightliness; and occasional contamination of streams. None of these problems is insurmountable and many quarries are presently operated in an acceptable fashion.

Data concerning the quantifiable environmental impacts of limestone mining are summarized in Table 16. The impacts are summarized in Table 14. Even though the quarrying operations may be objectionable as a neighborhood problem, they produce relatively small impacts on a tonnage basis. The major problem is dust (particulates). However, compared to the other operations in the glass system (Table 8), the impacts of limestone mining are quite small accounting for only 1 percent of the total system impacts.

TABLE 16

DATA FOR MINING OF 1 TON LIMESTONE

		Sources
Energy		89
Coal	0.00012 ton	
Distillate	0.16 gal.	
Residual	0.013 gal.	
Natural gas	9.3 cu ft	
Gasoline	0.049 gal.	
Electricity	2.0 kwhr	
Water volume	91 gal.	90
Process atmospheric emissions		
Particulates	13 lb	52
Transportation		
Rail	10 ton-miles	84
Water	26 ton-miles	86
Truck	42 ton-miles	67

E. Lime Manufacture

Lime is produced by calcining limestone. Limestone (calcium carbonate) is heated in a kiln to a high temperature so that any water present is driven off and the carbonate is broken up by the evolution of carbon dioxide. The product remaining is lime (calcium oxide). Significant environmental impacts occur due to fuel combustion and due to material losses. For 1 ton of lime produced approximately 0.8 ton of carbon dioxide is released. An additional 0.2 ton of material impacts on the environment in the form of solid waste and as dust (particulate emission). The data are summarized in Table 17. The impacts are summarized in Table 14.

TABLE 17

DATA FOR MANUFACTURE OF 1 TON LIME

		Sources
Virgin raw materials	4,000 lb	15
Energy		89
Coal	0.090 ton	
Distillate	0.17 gal.	
Residual	0.76 gal.	
Natural Gas	1,670 cu ft	
Gasoline	0.067 gal.	
Electricity	28 kwhr	
Water	270 gal.	90
Solid wastes	365 lb	15,52
Process atmospheric emissions		
Particulates	35 lb	15,52
Transportation		93
Rail	144 ton-miles	
Truck	54 ton-miles	

The most important impacts of lime manufacture are raw materials use and air and water pollution. The raw materials are mostly limestone which is a readily available mineral, so its use does not seriously deplete reserves. The air pollution problem is mainly particulates which arise from dust losses, although some arise from coal combustion. The water pollution problem is of particular interest because it comes entirely from acid coal mine drainage. Thus, the water pollution problem is generally beyond the control of the lime manufacturer.

Table 8 shows that the lime manufacturing impacts are a small percentage of the glass bottle profile. They account for 1 percent of the weighted impacts.

F. Natural Soda Ash Mining

Soda ash, which is the common name for sodium carbonate, is used in glass manufacture as a fluxing agent. Under the temperature conditions of a glass furnace the carbonate is converted to sodium oxide which lowers the melting and working temperature and decreases the viscosity of the melt. Sodium oxide is the second most abundant material in finished glass, constituting about 15 percent of the finished glass weight.

Soda ash is obtainable in either its natural form or in a manufactured form. This section of the chapter deals with its natural form which accounts for about 36 percent of the soda ash used by the glass industry.

The most abundant supply of natural soda ash (trona) is obtained from three mines near Green River, Wyoming. The crude trona is mined from beds nearly 1,500 feet below the surface using the room and pillar technique. The trona is processed and refined at the mine site to produce soda ash.

Detailed information is not available to assess accurately the energy impacts of trona mining. However, most of the mining techniques have been borrowed from existing coal mining technology so the energy impacts of trona mining were estimated by using coal mining data. The dominant energy use in the refining process is the calcining of bicarbonate to produce the carbonate. This impact was added to the "coal mining" impacts to produce the estimate of energy use for trona mining.

The estimate of the energy uses is summarized in Table 18. The other data in the table were obtained or estimated from literature sources concerning trona mining.

Summary Table 8 shows that natural soda ash mining produces fairly small environmental impacts as compared to the other operations in glass manufacture. However, the substantially greater use of energy as compared to the other mined minerals leads to higher atmospheric emissions than experienced by the other minerals' mining operations. Table 8 shows that soda ash mining accounts for less than 1 percent of the weighted impacts for bottle manufacture.

TABLE 18

DATA FOR MINING OF 1 TON NATURAL SODA ASH

		Sources
Energy Natural gas	480 cu ft	67
Water volume	1,200 gal.	90
Mining wastes	120 lb	16
Process atmospheric emission Particulates	10 lb	67
Transportation Rail	650 ton-miles	16,67

G. Soda Ash Manufacture

The principal means of manufacturing soda ash is by the Solvay process. Figure 3 depicts the overall process flow which combines limestone and salt to produce soda ash. Lime, ammonia and sodium bicarbonate are important intermediate materials.

Data relating to the impacts associated with producing the concentrated brine necessary for soda ash manufacture are shown in Table 19. The customary method of obtaining brine for Solvay process plants is to pump water into a natural underground salt dome and to pump out the concentrated brine. This procedure produces virtually no waste products except those due to fuel combustion to supply the necessary energy. Detailed data were not available to describe the energy requirements of this process so they were estimated by using census data for rock salt mining which includes many of the same basic operations as the hydraulic mining method. Impacts associated with brine production are all quite small as shown in Table 14. No significant contribution is made to bottle manufacture as shown in Table 8.

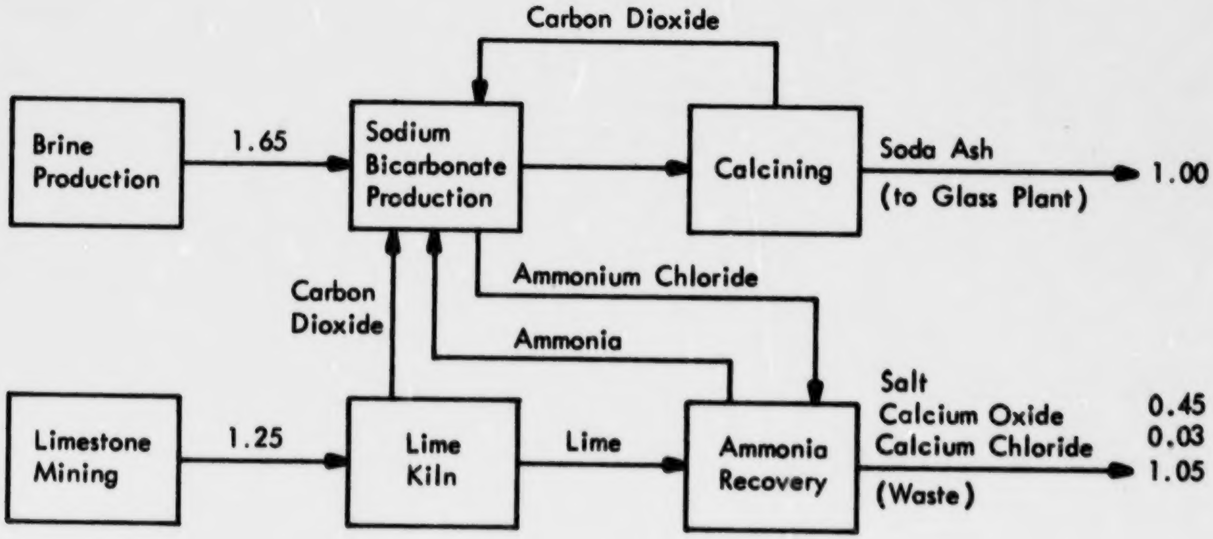
Carbon Dioxide
Brine Production
1.65
Sodium Bicarbonate Production
Calcining
Soda Ash
(to Glass Plant)
1.00
Carbon Dioxide
Ammonium Chloride
Ammonia
Limestone Mining
1.25
Lime Kiln
Lime
Ammonia Recovery
Salt
Calcium Oxide
Calcium Chloride
(Waste)
0.45
0.03
1.05

Figure 3 - Materials Requirements for the Manufacture of 1 Ton Soda Ash by the Solvay Process (ton)

TABLE 19

DATA FOR PRODUCTION OF 1 TON SALT AS BRINE

		Source
Energy		89
Electricity	0.85 kwhr	
Fuel oil	0.11 gal.	
Gas	169 cu ft	
Gasoline	0.014 gal.	
Water volume	1,000 gal.	67

Overall environmental impacts for manufacture of 1 ton of soda ash are quite high per ton output when compared to the other operations in the glass system as shown in Table 14. A basic factor effecting this is the inefficiency in utilization of raw materials (Table 20). Considerable quantities of salt which enter the process simply pass on through so that approximately 0.5 ton of salt must be disposed of as a solid waste for each ton of soda ash produced. In addition, over 1 ton of calcium chloride and calcium oxide is produced. Even though these materials are sometimes sold, they usually are simply dumped. Not only do these inefficiencies represent a solid waste problem but the impacts associated with the various mining and preparation processes are "wasted," they cannot be allocated to co-products; soda ash production must carry the full load.

Another important factor affecting the environmental profile of soda ash manufacture is the use of coal and residual oils as primary sources of fuel. These give rise to high values for atmospheric emissions.

Table 8 shows that soda ash manufacture contributes 9 percent of the total weighted impacts of bottle manufacture. Six impact categories occur to a significant degree.

H. Feldspar Mining

Feldspar is an aluminum silicate mineral which is used in glass manufacture to obtain aluminum oxide. This oxide acts as a stabilizer and improves the stability and durability of the glass microstructure. It is added in small quantities and generally makes up less than 3 percent of the total glass weight.

TABLE 20

DATA FOR MANUFACTURE OF 1 TON SODA ASH BY THE SOLVAY PROCESS

		Source
Virgin raw materials		16
Salt	3,300 lb	
Limestone	2,500 lb	
Other materials (ammonia, sodium sulfide)	9 lb	
Energy		16,67
Coal	0.235 ton	
Residual	16.7 gal.	
Gas	1,200 cu ft	
Coke	0.1 ton	
Water volume	16,000 gal.	90
Process solid wastes	3,340 lb	16
Process atmospheric emissions		
Ammonia	7 lb	43
Particulates	21 lb	49,52,67
Waterborne wastes		
Suspended solids	7 lb	67
Transportation		
Rail	220 ton-miles	85
Barge	116 ton-miles	88
Truck	25 ton-miles	67

added in small quantities and generally makes up less than 3 percent of the total glass weight.

Feldspar is mined in 13 states but North Carolina and California produce 65 percent of the nation's total. Hence, transportation expenses to bring feldspar to glass plants may be quite high. Feldspar is mined primarily by open pit quarry techniques. Usually drilling and blasting are required although this is not always so.

The data pertaining to the impacts associated with feldspar mining are in Table 21, with the impacts summarized in Summary Table 14. The dominant impact is the considerable mining waste associated with feldspar mining. More solid waste is associated with this operation per ton of material than any other operation for glass manufacture. Also, there is a significant amount of air pollution which is primarily dust produced by mining and crude ore processing.

TABLE 21

DATA FOR MINING OF 1 TON FELDSPAR

		Source
Energy		89
Distillate	3.8 gal.	
Gas	60 cu ft	
Gasoline	0.25 gal.	
Electricity	56 kwhr	
Water volume	4,500 gal.	91
Mining wastes	4,600 lb	102
Atmospheric emissions		67
Particulates	15 lb	
Transportation		67
Rail	500 ton-miles	

Overall, however, the effect on the weighted impacts is small. Table 8 shows that 2 percent of the glass bottle impacts are attributed to feldspar mining.

I. Glass Container Manufacture

Glass container manufacture is carried out in an integrated plant where raw materials are delivered and finished containers are shipped out. The raw materials are melted and refined in a glass furnace before being fed in a molten state to forming machines. These machines form and cool the glass container before annealing. After annealing, they are further cooled and packed for shipment. A considerable amount of glass breakage occurs inside the plant. This broken glass (cullet) is considered to be a valuable raw material and is recycled to the glass furnace. Typically, the raw material batch will include 15 percent cullet from internal sources.

Glass is a three dimensional random network of silicon and oxygen atoms with fluxes and stabilizers added. Thus, glass sand (silicon dioxide) is the primary raw material. Other important materials added include soda ash, lime or limestone and feldspar. In the glass furnace, soda ash is converted to sodium oxide which serves as a fluxing agent. The fluxing agents alter melting and working temperatures by decreasing the viscosity. Limestone yields lime (calcium oxide) in the glass furnace. Calcium oxide along with the aluminum oxide from feldspar are stabilizers and add desirable characteristics such as chemical durability to the final product. Other additives are made in small amounts to add color and to change refining characteristics for other purposes. Data pertaining to glass manufacture are in Table 22 with the corresponding impacts in Table 14.

Glass container plants are quite clean from an environmental effluent point of view as compared to many other types of industrial plants. This does not mean that glass plants are free of environmental ills, but the effluents are generally minimal. However, any large industrial plant may cause considerable local damage to the environment even though its impact per ton of material is quite low.

Table 8 shows that glass container manufacture accounts for 36 percent of the weighted container impacts. Energy use in container manufacture accounts for 23 percent of the total weighted impacts for the glass container system, and 56 percent of the total energy category for container manufacture.

The formation of glass requires a considerable amount of heat to be expended in melting the inorganic chemicals and in sustaining the temperatures at which the necessary chemical reactions and subsequent refining take place. However, the widespread use of natural gas in glass furnaces results in quite low atmospheric emissions for this sizable energy expenditure.

TABLE 22

DATA FOR MANUFACTURE OF 1 TON GLASS CONTAINERS

		Source
Virgin raw materials		67,68,88,102
Sand	1,320 lb	
Limestone	334 lb	
Soda ash (natural)	155 lb	
Feldspar	151 lb	
Other	40 lb	
Packaging		
Corrugated	132 lb	
Energy		88
Distillate	1.2 gal.	
Residual	5.5 gal.	
Gas	10,700 cu ft	
Gasoline	0.023 gal.	
Electricity	263 kwhr	
Water	870 gal.	88
Process solid waste	45 lb	67
Process atmospheric emissions		43
Particulates	2 lb	
Waterborne wastes		67,76
Oil	0.2 lb	
Transportation		93
Rail	50 ton-miles	
Barge	2 ton-miles	
Truck	186 ton-miles	

Other important impacts for glass plants are atmospheric emissions and waterborne wastes. The atmospheric emissions are primarily from fuel combustion; other emissions are only about 2 pounds of particulates and are of minor importance. However, in some localities the use of fluorspar in the glass furnace may give rise to troublesome fluoride emissions. Waterborne wastes from glass plants result from use of oils on the glass forming line. But the major water pollutant associated with glass plant operations is the acid coal mine drainage associated with coal consumed as an energy source.

J. Closures

In order to provide a 12-ounce beer bottle comparable to the 12-ounce can, it is necessary to consider impacts related to closure manufacture. The typical closure for a glass beer bottle is a steel crown with a plastic liner. A typical weight for such a closure is 0.0040 pound. For 1 million containers, then, it would require 4,000 pounds or 2 tons steel. It was assumed that the impacts for these closures would be approximated on a tonnage basis by the impacts for the manufacture of finished steel cans. The reader is referred to Chapter 4 for a discussion of these impacts.

K. Plastic Coated Bottles

A recent innovation in glass bottles has been the development of plastic coated bottles. These coatings, or jackets, have the advantage of reducing the bruising and breaking of bottles as they strike one another or other objects and also reduce glass shattering. The environmental profile of these bottles is somewhat better than conventional one-way bottles because they can be fabricated with 10 to 20 percent less glass in them. The reason why less glass is possible is because the break and shatter resistance of the bottle allows lighter weight construction.

Table 23 contains data to calculate the impact of the plastic jacket. Polystyrene foam is the jacket used on the bottles called "Plastishield" bottles. However, these data would serve as a good estimate for the plastic coatings used on other bottles. Table 11 shows, the amount of plastic required is so small it accounts for only about 3 percent of the total profile.

L. Paper Packaging

Paper packaging is used in significant quantities at two points in the beer bottle system. The first point is at the glass plant where the

TABLE 23

DATA FOR 1,000 POUNDS POLYSTYRENE FOAM JACKET

Materials		
	Crude Oil	966 lb.
	Natural Gas	316 lb.
	Additives	5 lb.
Energy		
	Natural Gas (internal combustion)	3,800 cu. ft.
	Natural Gas (heating)	17,300 cu. ft.
	Electricity	981 kwhr
Water		8,300 gal.
Industrial Solid Wastes		68 lb.
Process Atmospheric Emission		
	Hydrocarbons	77 lb.
	Sulfur Oxides	3 lb.
Waterborne Wastes		
	Dissolved Solids	12 lb.
	Oil	0.5 lb.
	BOD	2.2 lb.
	COD	2.5 lb.
	Suspended Solids	1.0 lb.
Transportation		
	Pipeline	131 ton-miles
	Barge	125 ton-miles
	Truck	210 ton-miles
	Rail	624 ton-miles

Source: 47

bottles are packed in corrugated containers for shipment to the bottling plant, and the second point is at the bottling plant where the filled containers are placed into paperboard packages such as "six pack" carriers.

The corrugated container is fabricated from two strong liners made of unbleached kraft paperboard with an inner fluted filler of corrugating medium. The corrugating medium can be made of recycled corrugated containers, or from a combination of types of virgin fibers. It is common in the glass industry to use a 100 percent virgin container, so we have based our example of a corrugated container on that premise.

Table 24 contains basic data relating to corrugated container manufacture. We have assumed that a corrugated container is fabricated from unbleached kraft linerboard which comprises 69 percent by weight of the box, and corrugating medium which is the remaining 31 percent. The corrugating medium is fabricated from fibers derived from two pulp types: 80 percent from NSSC pulp and 20 percent from unbleached kraft pulp.

Table 14 shows that the most serious environmental problem for the corrugated container manufacture is energy use. However, it should be noted that 10 million Btu, or 26 percent of this energy is derived from burning wood fiber. Thus, if only fossil fuels are considered, the energy problem is not as serious.

The second most important impact is air pollution. This is dominated by the incineration of waste digestion liquors from NSSC pulp mills. This procedure is rapidly declining because of pollution control regulations, but is still practiced to some extent.

The third most important problem is water pollution, which is caused by the basic wasteful nature of wood processing. Unacceptable fibers and other wood components are washed from the pulp and discarded as water pollutants.

Table 25 contains basic data for bleached paperboard product manufacture. The profile as seen on Table 25 is similar to that of corrugated boxes. However, the energy requirements are greater, water pollution is worse, but air pollution is less.

The air pollution from kraft mills differs from the air pollution from NSSC mills in that the most notable impact from kraft mills derives from odorous sulfur compounds. The horrible stench produced by the kraft pulping process is legendary, and where the odor is uncontrolled it produces a quite severe local impact.

TABLE 24

DATA FOR MANUFACTURE OF 1 TON CORRUGATED CONTAINERS

Virgin Raw Materials	
Wood fiber (bone dry basis)[a]	1,992 lb
Additives	140 lb
Energy	
Kraft Recovery Furnace	9.4×10^6 Btu
Auxiliary Boiler	16.8×10^6 Btu
Diesel	13.6 gal.
Electricity	320 kwhr
Water	29,400 gal.
Process Solid Waste	134 lb
Process Atmospheric Emissions	
Particulates	38 lb
Odorous Sulfur	5 lb
Sulfur Oxides	43 lb
Waterborne Wastes	
BOD	41 lb
Suspended Solids	19 lb
Transportation	
Rail	602 ton-miles
Truck	296 ton-miles
Water	12 ton-miles

---

[a] Thirty percent or 598 lb is derived from chips and wood residues.

Source: 48

TABLE 25

DATA FOR MANUFACTURE OF 1 TON BLEACHED KRAFT PAPERBOARD CARRIERS

Virgin Raw Materials	
Wood Fiber (bone dry basis)[a]	2,040 lb
Additives	140 lb
Energy	
Kraft recovery furnace	12.4×10^6 Btu
Auxiliary boiler	16.8×10^6 Btu
Diesel	13.8 gal.
Electricity	320 kwhr
Water	51,600 gal.
Process Solid Waste	134 lb
Process Atmospheric Emissions	
Particulates	38 lb
Odorous sulfur	7 lb
Waterborne Wastes	
BOD	50 lb
Suspended Solids	44 lb
Transportation	
Rail	644 ton-miles
Barge	12 ton-miles
Truck	308 ton-miles

---

[a] Thirty percent or 612 lb is derived from chips and wood residues.

Source: 48

Table 8 shows that the total paper packaging systems produce quite important impacts compared to the other operations. Thirty percent of the total glass bottle system impacts are allocated to packaging.

M. Bottle Filling

New bottles enter the filling plant and are placed on high speed automated lines which clean, fill, close, pasteurize and package the bottles. The bottles are rinsed with clean water which need not be heated and moved along the line by electric motors. The only step requiring significant amounts of fuel is the pasteurizing step, thus the overall impacts of this step are not large compared to other steps.

Of interest is the fact that the corrugated shipping cartons in which the bottles are received are saved and used for shipping the filled bottles. Thus, the only new packaging required is for the six pack carriers.

Table 26 contains data relating to beer filling plants reporting for one-way and returnable bottles. A distinction is made between on-premise and off-premise returnable beer bottles in regards the packaging requirements. The on-premise bottle is boxed in a closed corrugated carton which lasts approximately three trips. However, the off-premise carton requires a six pack carrier as well as a corrugated carton. We have assumed here that the 5-RET off-premise package only makes one trip, but the packaging could serve for multiple trips if returned to the same brewer.

Significant differences exist between one-way and returnable bottle impacts at the filling plant for several reasons. The most important are those associated with the returnable bottle. They are the energy necessary to heat the washing water, the use of caustic washing compounds, and the resulting water pollution. However, it is customary to use the waste caustic solution to neutralize the acid brewery wastes. Thus, the alkaline water pollutants are converted to wastewater treatment sludges and become part of the solid wastes burden.

In addition to the data related to beer bottles, additional data are included here for soft drink bottles. Up to the filling plant, the beer and soft drink bottles utilize the same type of manufacturing operations. This results from the fact that soft drink bottles are made from the same type of glass but differ in weight and style from beer bottles.

Table 27 summarizes the data for soft drink bottles. Both one-way and returnable bottles are included. The data for beer and soft drinks are quite similar, although differing somewhat in most categories.

TABLE 26

DATA FOR FILLING AND DELIVERY OF 1 MILLION 12-OUNCE BEER BOTTLES

Materials				
	Paper packaging			
		One way	58,000 lb	(bleached kraft)
		On-premise returnable	27,000 lb	(corrugated container)
		Off-premise returnable	78,000 lb	(corrugated container)
		(one trip packaging)	34,000 lb	(bleached kraft)
	Cleaning agents			
		Sodium Hydroxide	3,000 lb	
Energy				
	One way			
		Coal	1 ton	
		Residual	150 gal.	
		Natural gas	60,000 cu ft	
		Electricity	2,000 kwhr	
	Returnable			
		Coal	1 ton	
		Residual	570 gal.	
		Natural gas	225,000 cu ft	
		Electricity	2,000 kwhr	
Water				
	One way		300,000 gal.	
	Returnable		400,000 gal.	
Industrial Solid Wastes			2,000 lb	
Waterborne Wastes				
	Returnable			
		BOD	1,000 lb	
		Suspended solids	260 lb	
Transportation				
	One way			
		Rail	50,000 ton-miles	
		Truck	40,000 ton-miles	
	Returnable			
		Rail	100,000 ton-miles	
		Truck	40,000 ton-miles	

Source: 67

TABLE 27

DATA FOR FILLING AND DELIVERY OF 1 MILLION 16-OUNCE SOFT DRINK BOTTLES

Materials			
	Paper packaging		
		One way	28,600 lb (bleached kraft)
		Returnable	14,600 lb (bleached kraft)
	Cleaning agents		
		Sodium Hydroxide	2,500 lb
Energy			
	One way		
		Natural gas	123,000 cu ft
		Electricity	12,200 kwhr
	Returnable		
		Natural gas	184,000 cu ft
		Electricity	13,300 kwhr
Water			
	One way		200,000 gal.
	Returnable		300,000 gal.
Industrial Solid Wastes			1,000 lb
Waterborne Wastes			
	Returnable		
		Alkalinity	1,000 lb
		BOD	100 lb
		Suspended solids	200 lb
Transportation			
	One way	Gasoline	110 gal. diesel
			500 gal. gasoline
	Returnable	Gasoline	220 gal. diesel
			780 gal. gasoline

Source: 67

N. Solid Waste Disposal

The primary environmental impacts associated with solid waste disposal depends on the type of disposal taking place. Most of the solid waste stream in this country is disposed of on land. We will assume that 91 percent of solid waste is landfilled (or dumped) with the remaining 9 percent being incinerated. Recovery of materials from the post-consumer solid waste stream is practiced on a fairly small scale nationwide, so no recovery is included our disposal model.

Transportation is an important factor in disposal impacts. We have assumed a 20 mile average travel distance per load of refuse in a 20 yard compactor truck. Assuming that the truck efficiency is 5 miles per gallon of gasoline, and that the waste is compacted to 500 pounds per cubic yard, the fuel usage is 0.8 gallons gasoline per ton waste.

For the 9 percent of the "average" ton of solid waste incinerated, some air pollution results. However, the total pounds of pollutants generated by the 180 pounds (0.09 x 2,000 lb = 180 lb) of waste incinerated for each ton collected results in a total of 3.8 pounds of air pollution. The only significant contributor is carbon monoxide at 3.2 pounds. The remaining 0.6 pounds is distributed approximately equally among particulates,* sulfur oxides, hydrocarbons, nitrogen oxides and hydrogen chloride. However, we assume that inert materials such as glass and metals are essentially nonparticipants in the incineration process and are disposed of on land.

Table 28 contains the data from which impacts were calculated. Included are the volumes that solid waste occupies in a landfill. These numbers were derived by determining the theoretical densities of the materials. In actual fact, an unbroken bottle or an uncollapsed can often finds its way into landfills (or dumps). However, no data are available on typical behavior of the various containers in typical landfill operations. However, the important factor here is that some measure of relative volume of the various containers can be established and thus provide some estimate. Although data are lacking concerning all of the containers, it is our opinion that the volume occupied by the plastic container may be underestimated more than for the other containers. It is less likely that the plastic bottles will either compress like a can or break (or split) like a bottle than the conventional containers. On the other hand, the aluminum can will probably collapse and compress quite readily so that its relative volume may be overestimated here.

Table 8 shows that the impacts due to disposal are small, accounting for 5 percent of the overall glass container system.

---

* It is assumed that a 95 percent efficient precipitator is in place.

TABLE 28

DATA FOR DISPOSAL OF 1 TON SOLID WASTE

		Source
Energy		
Gasoline	0.8 gal.	67
Solid Waste Volume		67
Steel	4 cu ft/ton	
Glass and aluminum	12 cu ft/ton	
Paper and plastic[a]	33 cu ft/ton	
Process Atmospheric Emissions[b] (for combustible materials)		52
Carbon monoxide	3.2 lb	
Other	0.6 lb	

---

a/ This assumes that for 1 ton, there is 36 cu ft, but 9 percent is incinerated.

b/ For 180 pounds, or 9 percent of the waste. Nine percent is incinerated.

O. Nonreturnable and Returnable Glass Containers

At this point, the calculation of the environmental impacts of the glass container is straightforward. The material flow diagram (Table 6) indicates the amount of each material needed for the manufacture of 1 ton of glass containers. Summary Table 8 shows the results of performing the impact calculations for each of the materials needed in glass container manufacture.

For purposes of comparison, the above calculations may be converted to the basis of 1 million containers. Current data show that a typical one-way 12-ounce beer bottle weighs 0.41 pound. A spot check was made by weighing recently purchased bottles which verifies this weight. Thus, 1 million containers weigh 410,000 pounds or 205 tons. The impacts of 205 tons of glass containers are readily calculated. The impacts of 2 tons of steel closures need to be added as shown in Summary Table 8.

The impacts that should be attributed to the returnable glass bottle require close inspection. Current data[62,63] indicate that 12-ounce returnable beer bottles weigh about 0.61 pound per bottle (305 tons per million containers), or 50 percent more than the corresponding one-way bottle. In addition, in order to make the calculations comparable to the other container systems studied, all impacts must be considered including those which are incurred in preparing the returned container for refilling. Thus, we must consider transportation of the container from the retail site back to the bottler as well as impacts associated with cleaning the used bottle before refilling.

Of considerable importance in calculating impacts relating to returnable bottles is the number of times each bottle is reused, or "trippage." At present, the trippage experienced by on-premise returnable beer bottles is 19.[66,67] That is, on the average, each bottle is used 19 times. However, it is our opinion that the current returnable beer bottle is not comparable to the other container systems studied here. The usage of on-premise returnable beer bottles is by commercial customers such as taverns, as opposed to the personal take-home use experienced by other containers. An analogy can be drawn with the soft drink industry which experiences national average trippage of 15[66,67] which includes vending machine as well as supermarket and other take-home configurations. However, some soft drink industry spokesmen indicate that the actual trippage rate may be closer to 10 for the supermarket take-home package. One beer industry spokesman indicates that beer packages may experience even fewer trips in the supermarket configuration. Perhaps five trips or less would be experienced. It should be noted that good data concerning trip rates do not exist and the trippage actually achieved is quite difficult to determine accurately. Table 29 and Figure 4 contain the basic data for returnable bottle calculations.

TABLE 29

DATA FOR RETURNABLE GLASS CONTAINERS USED TO DELIVER 1 MILLION 12-OUNCE UNITS OF BEER

Glass Manufacture (where N = trippage)	305 tons ÷ N

(Other requirements on Table 6.13)

Source: 67

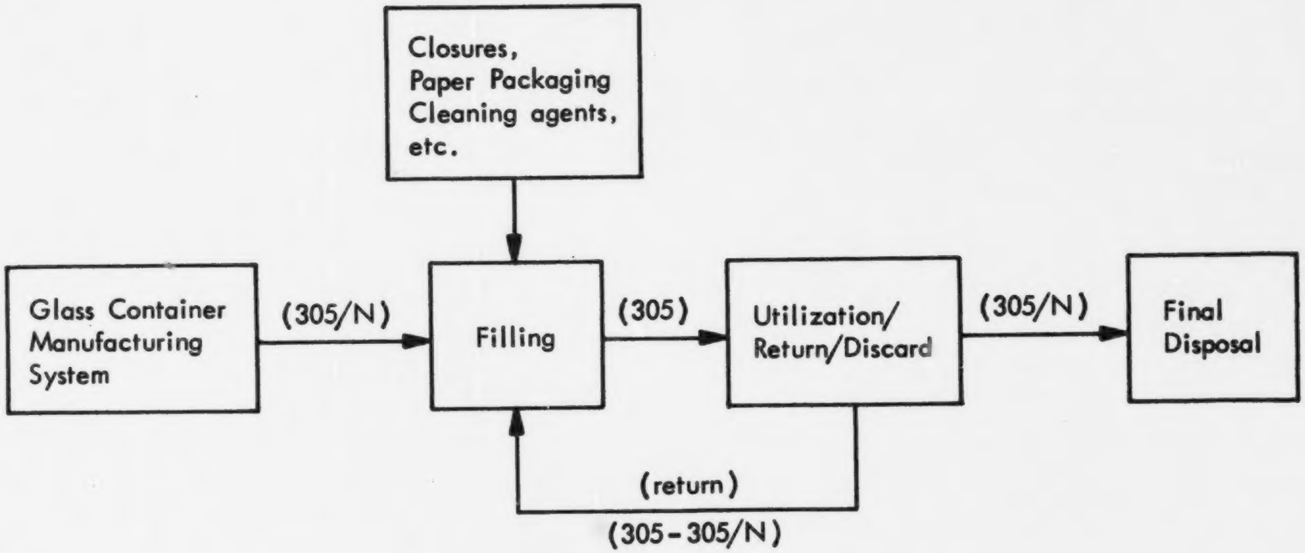
Closures,
Paper Packaging
Cleaning agents,
etc.
Glass Container
Manufacturing
System
(305/N)
Filling
(305)
Utilization/
Return/Discard
(305/N)
Final
Disposal
(return)
(305-305/N)

Figure 4 - Glass Flow to Provide Returnable Beer Bottles for 1 Million Containers at Any Trip Rate N (Tons)

P. Glass Recycling

Waste glass (known as cullet) is a valuable commodity to the glass industry. It is useful in glass furnaces to promote proper melting of the raw materials and is generally conceded to aid in the superior formation of glass. At the present time, most cullet is primarily an industrial scrap. Most of the cullet used is generated and recycled within the same glass plant, although glass container filling plants also routinely collect and sell their broken glass.

Several solid waste separation schemes are presently used on experimental, or pilot-plant basis to separate cullet from municipal solid waste streams. This has the advantage of reducing solid waste volume as well as providing a commodity of value to the glass industry.

Table 30 contains data pertinent to the operation of a hypothetical scaled up plant similar to the wet separation pilot plant designed by Black-Clawson Corporation. The pilot plant is in Franklin, Ohio.

TABLE 30

DATA FOR SEPARATION OF 1 TON GLASS CULLET FROM MUNICIPAL SOLID WASTE

Energy	
Residual oil	0.042 gal.
Electric	400 kwhr
Natural gas	8 cu ft
Postconsumer Solid Waste	-2,000 lb
Transportation	
Truck	100 ton-miles

Source: 67

CHAPTER III

ABS BOTTLE

This chapter contains the basic data and outlines the calculations made to determine the total environmental profile for ABS beer bottles. Three container options were studied: nonreturnable bottles, bottles made from 100 percent recycled resin, and 10-trip returnable bottles. A steel closure was used with each option.

Figure 5 shows a flow diagram for manufacturing the ABS bottle. Crude oil and natural gas are the principal raw materials required. Acrylonitrile, polybutadiene and styrene react to form the ABS resin. In the recycle option, the raw materials are the used, nonrefillable ABS bottle (which is cut up, melted, and processed to form other bottles), and the steel closure. The returnable bottle requires only cleaning materials and steel closures for raw materials.

This chapter discusses the ABS bottle systems in the following sequence.

A. Overview
B. Crude Oil Production
C. Benzene Manufacture
D. Natural Gas Production
E. Natural Gas Processing
F. Ethylene Manufacture
G. 1,3 Butadiene Manufacture
H. Ammonia Manufacture
I. Acrylonitrile Manufacture
J. Styrene Manufacture
K. Polybutadiene Manufacture
L. ABS Resin Manufacture
M. Bottle Fabrication
N. Container Options

A. Overview

This section contains the computer generated tables which summarize the environmental impacts of the ABS beer bottle. Table 31 shows the impacts for 1 million containers of each option. Table 32 (on two pages) shows the impacts that each subprocess contributes to the nonreturnable ABS bottle system. Table 33 contains the impacts for 1,000 pounds of each process in the ABS system.

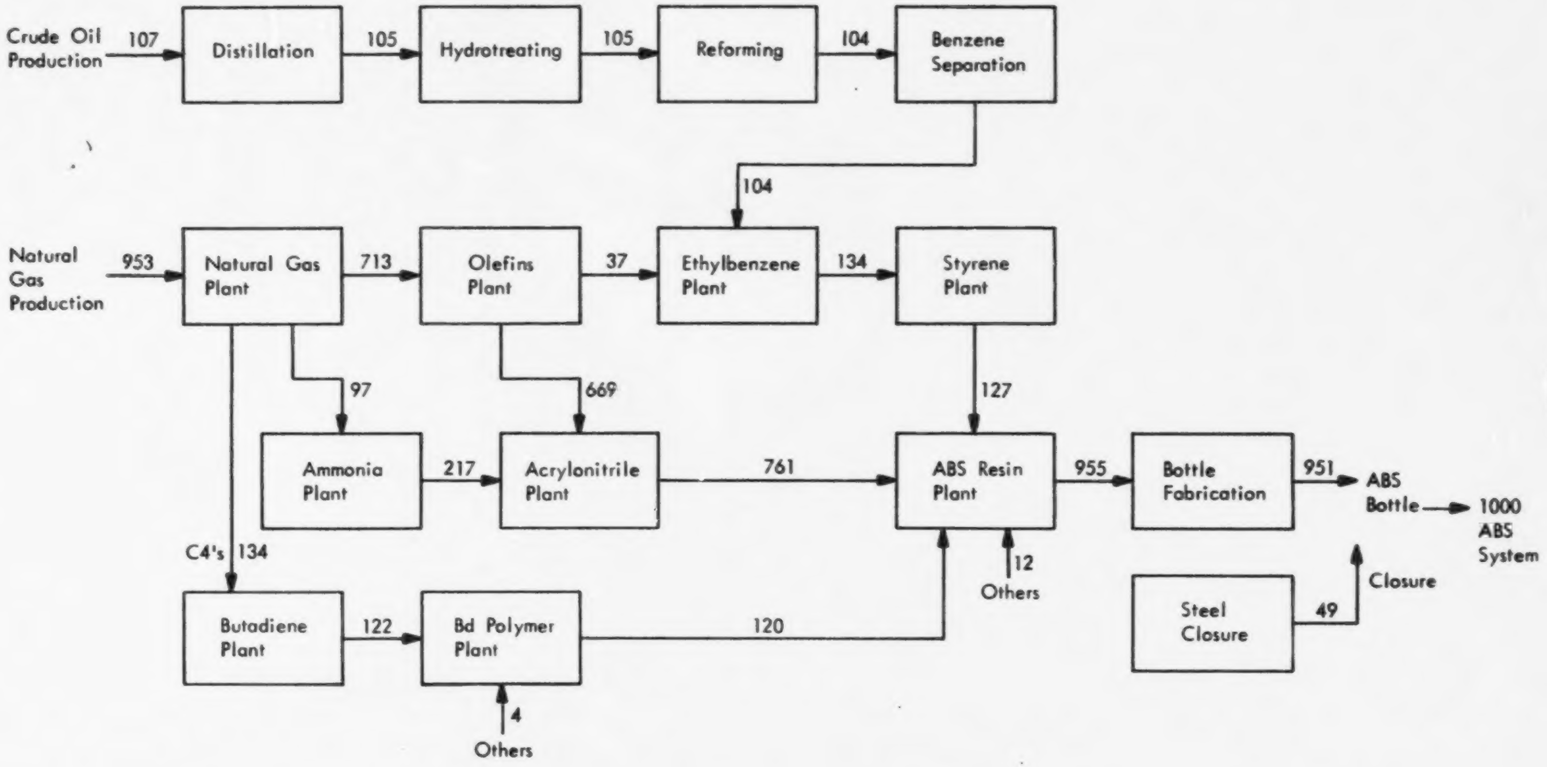
Crude Oil Production
107
Distillation
105
Hydrotreating
105
Reforming
104
Benzene Separation
104
Natural Gas Production
953
Natural Gas Plant
713
Olefins Plant
37
Ethylbenzene Plant
134
Styrene Plant
97
669
127
Ammonia Plant
217
Acrylonitrile Plant
761
ABS Resin Plant
955
Bottle Fabrication
951
ABS Bottle
1000 ABS System
C4's 134
12
Others
Butadiene Plant
122
Bd Polymer Plant
120
4
Others
Steel Closure
49
Closure

Figure 5 -Flow Diagram for Production of 1,000 Pounds of ABS Bottles (in pounds)

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TABLE 31

IMPACTS FOR 1 MILLION ABS BOTTLES IN EACH ABS OPTION

INPUT TO SYSTEMS

MATERIALS

NAME	UNITS	ONE WAY	ONE WAY 100 PCT RECYCLE	HYPOTHET 10 TRIP RETURNAB
MATERIAL WOOD FIBER	POUNDS	77267.	61134.	29308.
MATERIAL LIMESTONE	POUND	1649.	1649.	1649.
MATERIAL IRON ORE	POUND	3816.	3816.	3816.
MATERIAL SALT	POUND	0.	0.	3213.
MATERIAL GLASS SAND	POUND	0.	0.	0.
MATERIAL NAT SODA ASH	POUND	0.	0.	0.
MATERIAL FELDSPAR	POUND	0.	0.	0.
MATERIAL BAUXITE ORE	POUND	0.	0.	0.
MATERIAL PROCESS ADD	POUNDS	7861.	5028.	2710.
ENERGY PROCESS	MIL BTU	3961.	2195.	1360.
ENERGY TRANSPORT	MIL BTU	961.	206.	361.
ENERGY OF MATL RESOURCE	MIL BTU	1921.	1.	289.
WATER VOLUME	THOU GAL	3911.	2200.	1230.

OUTPUT FROM SYSTEMS

MATERIALS

NAME	UNITS	ONE WAY	ONE WAY 100 PCT RECYCLE	HYPOTHET 10 TRIP RETURNAB
SOLID WASTES PROCESS	POUND	4154.	9069.	5078.
SOLID WASTES FUEL COMB	POUND	10732.	8285.	2955.
SOLID WASTES MINING	POUND	24593.	21858.	16736.
SOLID WASTE POST-CONSUM	CUBIC FT	2536.	1078.	1684.
ATMOS PARTICULATES	POUND	3510.	2820.	1210.
ATMOS NITROGEN OXIDES	POUND	8747.	2078.	2381.
ATMOS HYDROCARBONS	POUND	6586.	1042.	1684.
ATMOS SULFUR OXIDES	POUND	5045.	3519.	2186.
ATMOS CARBON MONOXIDE	POUND	3891.	1246.	1446.
ATMOS ALDEHYDES	POUND	28.	14.	15.
ATMOS OTHER ORGANICS	POUND	69.	56.	43.
ATMOS ODOROUS SULFUR	POUND	773.	642.	242.
ATMOS AMMONIA	POUND	52.	12.	18.
ATMOS HYDROGEN FLOURIDE	POUND	0.	0.	0.
ATMOS LEAD	POUND	2.	1.	1.
ATMOS MERCURY	POUND	0.	0.	0.
ATMOSPHERIC CHLORINE	POUNDS	0.	0.	13.
WATERBORNE FLOURIDES	POUND	0.	0.	0.
WATERBORNE DISS SOLIDS	POUND	1194.	331.	410.
WATERBORNE BOD	POUND	2207.	1491.	1658.
WATERBORNE PHENOL	POUND	0.	0.	0.
WATERBORNE SULFIDES	POUND	1.	0.	0.
WATERBORNE OIL	POUND	124.	2.	21.
WATERBORNE COD	POUND	995.	19.	151.
WATERBORNE SUSP SOLIDS	POUND	2747.	2304.	1555.
WATERBORNE ACID	POUND	134.	106.	49.
WATERBORNE METAL ION	POUND	34.	27.	12.
WATERBORNE CHEMICALS	POUND	4.	0.	1.
WATERBORNE CYANIDE	POUND	0.	0.	0.
WATERBORNE ALKALINITY	POUND	0.	0.	0.
WATERBORNE CHROMIUM	POUND	0.	0.	0.
WATERBORNE IRON	POUND	1.	0.	0.
WATERBORNE ALUMINUM	POUND	1.	0.	0.
WATERBORNE NICKEL	POUND	1.	0.	0.
WATERBORNE MERCURY	POUND	0.	0.	0.
WATERBORNE LEAD	POUND	0.	0.	0.

TABLE 31 (Concluded)

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                                                   SUMMARY OF SYSTEMS

                                                      ONE WAY          ONE WAY          HYPOTHET
                                                                       100 PCT          10 TRIP
                                                                       RECYCLE          RETURNAB

SUMMARY OF ENVIRONMENTAL IMPACTS
        NAME                        UNITS

        RAW MATERIALS             POUNDS              90593.           71628.           40696.
        ENERGY                    MIL BTU              6843.            2402.            2010.
        WATER                     THOU GAL             3911.            2200.            1230.
        INDUSTRIAL SOLID WASTES   CUBIC FT              600.             529.             334.
        ATM EMMISSIONS            POUNDS              28701.           11430.            9240.
        WATERBORNE WASTES         POUNDS               7443.            4281.            3858.
        POST-CONSUMER SOL WASTE   CUBIC FT             2536.            1078.            1684.

INDEX OF ENVIRONMENTAL IMPACTS
        NAME                       STANDARD
                                    VALUES

        RAW MATERIALS               67634.              134              106               60
        ENERGY                       3752.              182               64               54
        WATER                        2447.              160               90               50
        INDUSTRIAL SOLID WASTES       488.              123              108               69
        ATM EMMISSIONS              16457.              174               69               56
        WATERBORNE WASTES            5194.              143               82               74
        POST-CONSUMER SOL WASTE      1766.              144               61               95

        UNWEIGHTED INDEX                               1060              580              458

WEIGHTED INDEX OF ENVIRONMENTAL IMPACTS
        NAME                        WEIGHT

        RAW MATERIALS                  .05                7                5                3
        ENERGY                         .40               73               26               21
        WATER                          .05                8                4                3
        INDUSTRIAL SOLID WASTES        .05                6                5                3
        ATM EMMISSIONS                 .20               35               14               11
        WATERBORNE WASTES              .20               29               16               15
        POST-CONSUMER SOL WASTE        .05                7                3                5

        WEIGHTED COMPOSITE INDEX                        165               73               61
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TABLE 32

IMPACTS FOR 1,000 POUNDS OF THE ABS SYSTEM - ONE-WAY BOTTLES

INPUT TO SYSTEMS

MATERIALS NAME	UNITS	CRUDE OIL PROD 107 LB	BENZENE MAN 104 LB	NATURAL GAS PROD 953 LB	NATURAL GAS PROCESS 944 LB	OLEFINS MAN 706 LB	BUTADIEN MAN 122 LB	AMMONIA MAN 217 LB	ACRYLO MAN 761 LB	STYRENE MAN 127 LB	POLY BD MAN 120 LB	ABS RESIN MAN 955 LB	ABS BOTTLE FAB 951 LB	ABS CONT SYS TRANS 1000 LB	STEEL CLOSURE MAN 49 LB	FILLING BOTTLES 1000 LB	PACKAGE	DISPOSAL
MATERIAL WOOD FIBER	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	953.159	0.000
MATERIAL LIMESTONE	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	20.341	0.000	0.000	0.000
MATERIAL IRON ORE	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	47.109	0.000	0.000	0.000
MATERIAL SALT	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL GLASS SAND	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FEL SPAR	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL [illegible]	POUNDS	.291	.520	0.000	0.000	.141	3.172	.976	3.805	.940	3.936	12.226	0.000	0.000	3.431	0.030	67.650	0.000
ENERGY PROCESS	MIL BTU	.009	.495	.046	6.662	1.951	1.034	1.101	.882	.842	.377	6.076	7.705	0.000	1.240	1.937	18.293	0.000
ENERGY TRANSPORT	MIL BTU	.013	0.000	.473	0.000	4.648	0.000	0.000	0.000	0.000	0.000	0.000	0.000	4.431	.021	0.000	1.760	.159
ENERGY OF MATL RESOURCE	MIL BTU	1.926	0.000	21.334	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.414	0.000	0.000	.012	0.000	0.000	0.000
WATER VOLUME	THOU GAL	.038	.449	.037	.354	.936	.588	.000	10.511	1.451	.405	2.414	2.385	.263	1.326	3.739	22.368	.007

OUTPUT FROM SYSTEMS

MATERIALS NAME	UNITS	CRUDE OIL PROD 107 LB	BENZENE MAN 104 LB	NATURAL GAS PROD 953 LB	NATURAL GAS PROCESS 944 LB	OLEFINS MAN 706 LB	BUTADIEN MAN 122 LB	AMMONIA MAN 217 LB	ACRYLO MAN 761 LB	STYRENE MAN 127 LB	POLY BD MAN 120 LB	ABS RESIN MAN 955 LB	ABS BOTTLE FAB 951 LB	ABS CONT SYS TRANS 1000 LB	STEEL CLOSURE MAN 49 LB	FILLING BOTTLES 1000 LB	PACKAGE	DISPOSAL
SOLID WASTES PROCESS	POUND	.065	.104	0.000	0.000	.706	.040	.095	.009	.127	.012	1.050	.951	0.000	20.195	24.692	84.256	0.000
SOLID WASTES FUEL COMB	POUND	.040	.246	.218	.515	2.457	1.521	.136	3.090	.221	0.000	12.597	34.915	.616	1.194	1.477	73.211	.019
SOLID WASTES MINING	POUND	.059	.443	.315	.772	3.605	2.242	.208	4.434	.331	0.000	16.761	52.373	0.000	164.396	0.040	40.403	0.000
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	31.300
ATMOS PARTICULATES	POUND	.012	.042	.000	.090	.299	.165	.035	.306	.037	.007	1.302	3.461	.010	1.320	.000	34.371	.013
ATMOS NITROGEN OXIDES	POUND	.043	1.110	2.082	31.025	24.291	1.141	1.345	.547	1.057	.475	7.369	6.742	12.191	.777	1.965	15.521	.153
ATMOS HYDROCARBONS	POUND	.173	1.265	10.316	20.281	10.118	1.046	1.004	3.598	1.512	5.323	6.040	2.017	5.296	1.102	1.240	7.226	.262
ATMOS SULFUR OXIDES	POUND	.027	.513	.161	.354	1.310	.765	.005	1.533	.122	.006	6.256	17.325	1.786	1.060	2.732	28.199	.020
ATMOS CARBON MONOXIDE	POUND	.026	.326	.783	10.332	7.982	.339	.409	.143	.308	.140	2.094	1.019	12.328	.312	.551	6.349	0.004
ATMOS ALDEHYDES	POUND	.001	.007	.004	.000	.003	.002	.002	.002	.001	.001	.011	.017	.143	.002	.007	.111	.010
ATMOS OTHER ORGANICS	POUND	.000	.006	.001	.000	.006	.003	.004	.001	.003	.001	.019	.016	.125	.002	.006	.000	.571
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.052	0.000	9.484	0.000
ATMOS AMMONIA	POUND	.000	.006	.000	0.000	0.009	0.000	.477	0.000	0.000	0.000	0.000	0.000	.010	.131	.001	.012	.303
ATMOS HYDROGEN FLUORIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.000	0.000	.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.018	.000	.000	.003	.032
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.000	0.000	.000	.000	0.000	.000	.000	.000	0.000
ATMOSPHERIC CHLORINE	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	1.182	.142	3.015	1.087	1.030	.130	.179	.065	.134	.062	.807	.510	2.077	.113	.323	3.037	.658
WATERBORNE BOD	POUND	.003	.006	.000	.000	1.412	.542	.011	2.283	.372	.044	.071	.001	.005	.009	.000	22.359	.000
WATERBORNE PHENOL	POUND	.000	.001	.000	.000	.000	.000	.000	.000	.000	0.000	.003	.000	.002	.000	.000	.002	.000
WATERBORNE SULFIDES	POUND	.000	.001	.000	.000	.000	.000	.000	.000	.000	0.000	.000	.001	.002	.000	.000	.003	.000
WATERBORNE OIL	POUND	.000	.002	.000	.000	1.271	.008	.011	.041	.060	.008	.077	.001	.033	.026	.000	.003	.000
WATERBORNE COD	POUND	.000	.013	.000	.000	3.602	.042	.050	4.719	.400	.100	2.370	.005	.021	.001	.002	.025	.001
WATERBORNE SUSP SOLIDS	POUND	.000	.007	.000	.000	2.048	.125	.011	.034	.372	.150	.507	.003	.013	11.908	.001	18.242	.000
WATERBORNE ACID	POUND	.001	.004	.003	.008	.037	.023	.002	.047	.003	0.000	.140	.531	.004	.223	.071	.510	.005
WATERBORNE METAL ION	POUND	.000	.001	.001	.002	.009	.006	.001	.017	.001	0.000	.088	.133	.001	.046	.010	.127	.000
WATERBORNE CHEMICALS	POUND	0.000	0.000	0.000	0.000	0.000	0.000	.108	0.000	0.000	0.000	0.000	0.000	0.000	.002	0.000	0.000	0.000
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.001	0.000	0.000	.041	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.002	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.015	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.015	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	[illegible]	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	[illegible]	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE LEAD	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 32 (Concluded)

SUMMARY OF SYSTEMS

NAME	UNITS	CRUDE OIL PROD 107 LB	BENZENE MAN 104 LB	NATURAL GAS PROD 953 LB	NATURAL GAS PROCESS 944 LB	OLEFINS MAN 706 LB	BUTADIEN MAN 122 LB	AMMONIA MAN 217 LB	ACRYLO MAN 761 LB	STYRENE MAN 127 LB	POLY HD MAN 128 LB	ABS RESIN MAN 955 LB	ABS BOTTLE FAB 951 LB	ABS CONT SYS TRANS 1000 LB	STEEL CLOSURE MAN 49 LB	FILLING BOTTLES 1000 LB	PACKAGE	DISPOSAL
SUMMARY OF ENVIRONMENTAL IMPACTS																		
RAW MATERIALS	POUNDS	.201	.520	0.000	0.000	.161	3.172	.976	3.005	.940	3.936	12.226	0.000	0.000	70.901	0.000	1020.000	0.000
ENERGY	MIL BTU	1.948	.895	21.850	6.642	6.599	1.038	1.101	.682	.842	.372	6.509	7.705	4.831	1.332	1.937	20.061	.109
WATER	THOU GAL	.008	.449	.037	.354	.936	.568	.666	10.511	1.451	.405	2.814	2.385	.243	1.326	3.739	22.360	.007
INDUSTRIAL SOLID WASTES	CUBIC FT	.002	.011	.007	.017	.092	.053	.006	.112	.009	.000	.436	1.191	.008	2.508	.446	2.510	.000
ATM EMMISSIONS	POUNDS	.274	3.306	13.428	62.082	44.010	3.507	4.011	6.180	3.040	5.953	25.044	31.999	32.725	4.701	7.460	101.356	5.065
WATERBORNE WASTES	POUNDS	1.183	.175	3.819	1.097	9.487	.741	.373	7.776	1.843	.369	4.613	1.186	2.127	12.329	.416	44.309	.088
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	31.306
INDEX OF ENVIRONMENTAL IMPACTS	STANDARD VALUES																	
RAW MATERIALS	111.688	0	0	0	0	0	3	1	3	1	4	11	0	0	63	0	913	0
ENERGY	8.468	23	11	259	79	78	12	13	8	10	4	77	91	57	16	23	237	1
WATER	4.829	0	9	1	7	19	12	14	218	30	8	58	49	5	27	77	463	0
INDUSTRIAL SOLID WASTES	.741	0	2	1	2	12	7	1	15	1	0	59	161	1	338	60	339	0
ATM EMMISSIONS	35.436	1	9	38	175	124	10	11	17	9	17	71	90	92	13	21	286	14
WATERBORNE WASTES	9.189	13	2	42	12	103	8	4	85	20	4	50	13	23	134	5	482	1
POST-CONSUMER SOL WASTE	3.131	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1000
UNWEIGHTED INDEX		37	33	341	275	336	52	44	346	71	37	326	404	178	591	186	2720	1016
WEIGHTED INDEX OF ENVIRONMENTAL IMPACTS	WEIGHT																	
RAW MATERIALS	.05	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0	46	0
ENERGY	.40	9	4	103	31	31	5	5	3	4	2	31	36	23	6	9	95	1
WATER	.05	0	0	0	0	1	1	1	11	2	0	3	2	0	1	4	23	0
INDUSTRIAL SOLID WASTES	.05	0	0	0	0	1	0	0	1	0	0	3	8	0	17	3	17	0
ATM EMMISSIONS	.20	0	2	8	35	25	2	2	3	2	3	14	18	18	3	4	57	3
WATERBORNE WASTES	.20	3	0	8	2	21	2	1	17	4	1	10	3	5	27	1	96	0
POST-CONSUMER SOL WASTE	.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50
WEIGHTED COMPOSITE INDEX		12	6	119	68	79	10	9	35	12	6	62	67	46	57	21	334	54

TABLE 33

IMPACTS FOR 1,000 POUNDS OF EACH PROCESS FOR ABS BOTTLES

SUMMARY OF SYSTEMS

SUMMARY OF ENVIRONMENTAL IMPACTS NAME	UNITS	CRUDE OIL PROD	BENZENE MAN	NATURAL GAS PROD	NATURAL GAS PROCESS	ETHYLENE MAN	BUTADIEN MAN	AMMONIA MAN	ACRYLO MAN	STYRENE MAN	POLY BD MAN	ABS RESIN MAN	ABS BOTTLE FAB
RAW MATERIALS	POUNDS	1.886	5.000	0.000	0.000	.200	26.000	4.500	5.000	7.400	32.800	12.800	0.000
ENERGY	MIL BTU	18.395	8.607	22.936	7.036	9.346	8.507	5.075	.896	6.630	3.099	6.816	8.102
WATER	THOU GAL	.078	4.316	.039	.375	1.326	4.659	3.069	13.812	11.422	3.372	2.946	2.508
INDUSTRIAL SOLID WASTES	CUBIC FT	.021	.109	.008	.018	.131	.431	.027	.148	.072	.001	.457	1.253
ATM EMMISSIONS	POUNDS	2.605	31.773	14.040	65.765	62.337	28.748	18.486	8.121	23.937	49.605	26.276	33.648
WATERBORNE WASTES	POUNDS	11.055	1.686	4.008	1.163	13.437	5.665	1.718	10.219	14.512	3.073	4.830	1.247
POST-CONSUMER SOL WAST	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

INDEX OF ENVIRONMENTAL IMPACTS NAME	STANDARD VALUES	CRUDE OIL PROD	BENZENE MAN	NATURAL GAS PROD	NATURAL GAS PROCESS	ETHYLENE MAN	BUTADIEN MAN	AMMONIA MAN	ACRYLO MAN	STYRENE MAN	POLY BD MAN	ABS RESIN MAN	ABS BOTTLE FAB
RAW MATERIALS	10.081	19	50	0	0	2	258	45	50	74	326	127	0
ENERGY	11.082	166	78	207	63	84	77	46	8	60	28	62	73
WATER	4.827	2	89	1	8	27	97	64	286	237	70	61	52
INDUSTRIAL SOLID WASTES	.291	7	38	3	6	45	148	9	51	25	0	157	431
ATM EMMISSIONS	40.033	7	79	35	164	156	72	46	20	60	124	66	84
WATERBORNE WASTES	7.566	146	22	53	15	178	75	23	135	192	41	64	17
POST-CONSUMER SOL WASTE	0.000	0	0	0	0	0	0	0	0	0	0	0	0
UNWEIGHTED INDEX		347	356	299	256	492	727	233	550	648	589	537	657

WEIGHTED INDEX OF ENVIRONMENTAL IMPACTS NAME	WEIGHT	CRUDE OIL PROD	BENZENE MAN	NATURAL GAS PROD	NATURAL GAS PROCESS	ETHYLENE MAN	BUTADIEN MAN	AMMONIA MAN	ACRYLO MAN	STYRENE MAN	POLY BD MAN	ABS RESIN MAN	ABS BOTTLE FAB
RAW MATERIALS	.05	1	2	0	0	0	13	2	2	4	16	6	0
ENERGY	.40	66	31	83	25	34	31	18	3	24	11	25	29
WATER	.05	0	4	0	0	1	5	3	14	12	3	3	3
INDUSTRIAL SOLID WASTES	.05	0	2	0	0	2	7	0	3	1	0	8	22
ATM EMMISSIONS	.20	1	16	7	33	31	14	9	4	12	25	13	17
WATERBORNE WASTES	.20	29	4	11	3	36	15	5	27	38	8	13	3
POST-CONSUMER SOL WASTE	.05	0	0	0	0	0	0	0	0	0	0	0	0
WEIGHTED COMPOSITE INDEX		97	59	101	61	104	85	37	53	91	63	68	74

TABLE 33 (Concluded)

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INPUTS TO SYSTEMS

MATERIALS NAME	UNITS	CRUDE OIL PROD	BENZENE MAN	NATURAL GAS PROD	NATURAL GAS PROCESS	ETHYLENE MAN	BUTADIEN MAN	AMMONIA MAN	ACRYLO MAN	STYRENE MAN	POLY BD MAN	ABS RESIN MAN	ABS BOTTLE FAB	ABS RECYCLE
MATERIAL [illegible]	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL [illegible]	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL [illegible]	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL [illegible]	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL [illegible] ASH	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL [illegible]	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL [illegible]	POUNDS	1.880	5.000	0.000	0.000	.200	26.000	4.500	5.000	7.400	32.000	12.000	0.000	5.000
ENERGY PROCESS	MIL BTU	.041	8.607	.049	7.036	2.763	8.507	5.075	.496	6.630	3.099	6.356	8.102	.477
ENERGY TRANSPORT	MIL BTU	.124	0.000	.447	0.000	6.583	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ENERGY OF MATL RESOURCE	MIL BTU	16.000	0.000	22.341	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.460	0.000	0.000
WATER VOLUME	THOU GAL	.078	4.316	.039	.375	1.326	4.659	3.069	13.812	11.422	3.372	2.946	2.508	.186

OUTPUTS FROM SYSTEMS

MATERIALS NAME	UNITS	CRUDE OIL PROD	BENZENE MAN	NATURAL GAS PROD	NATURAL GAS PROCESS	ETHYLENE MAN	BUTADIEN MAN	AMMONIA MAN	ACRYLO MAN	STYRENE MAN	POLY BD MAN	ABS RESIN MAN	ABS BOTTLE FAB	ABS RECYCLE
SOLID WASTES PROCESS	POUND	.400	1.000	0.000	0.000	1.000	.740	.440	.800	1.000	.100	1.100	1.000	11.000
SOLID WASTES FUEL COMB	POUND	.378	2.842	.229	.545	3.400	12.470	.630	4.060	1.740	0.000	13.096	36.714	2.163
SOLID WASTES MINING	POUND	.552	4.263	.331	.018	5.220	10.705	.957	6.090	2.610	0.000	19.645	55.071	3.265
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS PARTICULATES	POUND	.113	.788	.084	.096	.424	1.349	.160	.402	.245	.061	1.363	3.640	.414
ATMOS NITROGEN OXIDES	POUND	.400	10.749	2.185	32.065	34.407	9.764	6.430	.704	8.319	3.961	7.695	7.090	.418
ATMOS HYDROCARBONS	POUND	1.614	11.469	10.825	21.484	14.331	8.577	7.394	4.720	11.403	44.355	8.471	2.962	.175
ATMOS SULFUR OXIDES	POUND	.251	4.930	.169	.375	1.056	6.274	.391	2.015	.957	.047	6.551	10.210	1.073
ATMOS CARBON MONOXIDE	POUND	.221	3.132	.822	10.945	11.306	2.742	1.805	.188	2.429	1.165	2.166	1.703	.100
ATMOS ALDEHYDES	POUND	.005	.063	.004	.000	.005	.015	.008	.002	.010	.005	.011	.010	.001
ATMOS OTHER ORGANICS	POUND	.001	.041	.001	.000	.009	.027	.019	.002	.024	.012	.010	.017	.001
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS AMMONIA	POUND	.000	.040	.000	0.000	0.000	0.000	2.200	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS HYDROGEN FLUORIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.000	0.000	.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.000	0.000	.000	.000	.000
ATMOSPHERIC CHLORINE	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	11.047	1.362	4.003	1.152	1.470	1.134	.026	.054	1.059	.513	.045	.536	.032
WATERBORNE BOD	POUND	.000	.035	.000	.000	2.000	.750	.050	3.000	2.430	.410	.601	.001	.100
WATERBORNE PHENOL	POUND	.000	.010	.000	.000	.000	.000	.000	.000	.000	0.000	.000	.001	.000
WATERBORNE SULFIDES	POUND	.000	.013	.000	.000	.000	.000	.070	.000	.000	0.000	.000	.001	.000
WATERBORNE OIL	POUND	.000	.020	.000	.000	1.800	.050	.050	.046	.470	.070	.000	.001	.000
WATERBORNE COD	POUND	.000	.120	.000	.000	5.201	3.292	.230	6.201	7.040	.030	2.482	.006	.200
WATERBORNE SUSP SOLIDS	POUND	.090	.070	.000	.000	2.400	.201	.050	.400	2.430	1.250	.531	.004	.200
WATERBORNE ACID	POUND	[illegible]	.043	.003	.008	.053	.190	.010	.062	.026	0.000	.199	.550	.033
WATERBORNE METAL ION	POUND	.001	.011	.001	.002	.013	.047	.002	.015	.007	0.000	.050	.140	.000
WATERBORNE CHEMICALS	POUND	0.000	0.000	0.000	0.000	0.000	0.000	.500	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.001	0.000	0.000	.001	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.002	0.000	0.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.016	0.000	0.000
WATERBORNE [illegible]	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.016	0.000	0.000
WATERBORNE [illegible]	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.008	0.000	0.000
WATERBORNE [illegible]	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE [illegible]	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

For the ABS bottle we will use glass bottle filling and distribution numbers. The disposal data will also be based on the glass system data in Chapter II.

The ABS resin manufacture described in this chapter is a hypothetical case. The quantities of materials used are estimates. The actual materials balance used in industry is proprietary. Our purpose in choosing the ABS system, with estimated values, is to present a typical plastics manufacturing process, which hopefully will approximate the impacts of various barrier bottle manufacturing processes.

Figure 5 shows a flow diagram for manufacturing 1,000 pounds of the ABS system. The values represent pounds of materials required from each process. In the computer generated tables, crude oil and natural gas quantities have been counted as their energy equivalent rather than as pounds of raw materials. The raw materials listed in the tables refer to additives such as catalysts, material packaging, etc.

B. Crude Oil Production

In drilling a well, a petroleum engineer must select a location compatible with property boundaries and reservoir engineering analyses. Provisions must be made for fuel and water supplies, and mud pits for storage of drilling muds and settling of cuttings from used muds.

More than 80 percent of modern wells and all deep wells are drilled by the rotary process. In this process, a bit is turned at the bottom of the hole. Drilling mud is pumped through the drill pipe to cool the bit and flush drill cuttings to the surface. The mud also provides pressure to prevent collapse of the sides of the hole before casing is inserted, and it must be heavy enough to block the flow of gas, oil and brine into the drill hole to prevent expensive and dangerous eruptions from the well.[3/]

After drilling to an intrusion area, the hole is protected by inserting a casing. The casing is normally protected by pumping cement through it, and permitting the cement to rise along the outside of the casing toward the ground surface. In some instances, the casing must be set prior to completion of the well. This occurs when the normal hydrostatic pressure of 0.465 psi per foot of depth is exceeded. Proper setting of the casing is mandatory to prevent sloughing off around the casing in high pressure zones. If the hydrocarbons and brine were allowed to work their way along the outside of the casing, pollution of an upper zone could occur, and result in contamination of a water supply or the surface of the ground at the point where the pollutants break through.

Upon completion of the well construction, production can begin. Oil pools produce primarily under four mechanisms: gas expansion, gas-cap drive, water drive, and gravity drainage. The rates at which the hydrocarbon fluids can be withdrawn from a reservoir depend on the number of wells draining the reservoir, the average thickness of the formation, and the permeability of the reservoir rock for these fluids. Secondary methods such as acid treatment, miscible displacement, addition of surface active agents, and in-situ combustion, can improve recovery efficiency.

Once production is started, the products are transported mainly by pipelines to oil field tank batteries or refinery storage vessels. Preliminary treatment involves separation of hydrocarbons from brine and settleable solids. The hydrocarbons are then processed by a gas plant or refinery.

Detailed information is scarce concerning the ways in which drilling fluids, drilling muds, well cuttings, and well treatment chemicals may contribute to pollution. Studies have been made about well blowout and communication between fresh water aquifers and oil bearing sands. Several publications are available about oil field brine disposal by subsurface injection.[56]

The data below list the approximate amounts of acids used in the U.S. in 1 year for oil and gas well treatment.[20]

ACIDS USED FOR WELL TREATMENT

Acid	Gal/yr	Gal/BBL Crude Produced
Hydrochloric	8.7×10^7	2.2×10^{-2}
Formic	2.0×10^6	5.2×10^{-5}
Acetic	1.0×10^6	2.6×10^{-5}

Also approximately 30×10^5 pounds of inhibitor and 37×10^5 pounds of additives are used per year in well treatment. The total domestic crude production in 1971 was 3,296,612,000 barrels.[98] The quantity of inhibitors per barrel of crude was 9.0×10^{-4} pounds, the quantity of additives, 11.2 $\times 10^{-4}$ pounds per barrel. Since these products are injected into the subsurface reservoir, the amount of pollution to fresh water aquifers is probably very small. The drilling muds used prior to production are usually expensive and therefore merit special handling to prevent excessive losses. However, most spent muds are left in open slush pits to permit evaporation of liquids. Most pits are earth filled when evaporation is complete. Some remain in limited service to contain the effluents from well servicing.

Several sources of pollution resulting from oil field operations are:

1. Well blowout - resulting in surface and subsurface contamination.

2. Dumping of oil based drilling muds, oil soaked cuttings and treatment chemicals.

3. Crude oil escape from pipeline leaks, overflow of storage vessels and rupture of storage and transport vessels.

4. Discharge of bottom sediment from storage vessels.

5. Subsurface disposal of brine into a formation which would permit migration of the brine into area which could result in pollution of fresh water or contribute toward other natural disasters.

6. Escape of natural gas containing hydrogen sulfide could pollute fresh water supplies and local atmosphere.

A significant waste product resulting from oil and gas production is brine. The amount of brine produced can vary from zero to 95 percent of production. It is estimated by the American Petroleum Institute that 2.5 barrels of brine per barrel of oil is typical. However, 90 percent of this is disposed of in some acceptable manner such as subsurface disposal, or evaporation. The remainder is allowed to contaminate surface or subsurface fresh water streams.

Since 25 percent by weight of the average production from an oil well is natural gas, 75 percent of the total brine production was allocated to oil production.

The process loss pollutants are evaporated hydrocarbons, and were estimated from data obtained from the Los Angeles County Air Pollution Control District.[40]

See Table 34 for environmental impacts related to crude oil production. Note that the crude oil has been counted as its energy equivalent rather than pounds of raw materials. The resource energy accounts for 98.9 percent of the total energy for production of 1,000 pounds of crude oil.

TABLE 34

DATA FOR PRODUCTION OF 1,000 POUNDS OF CRUDE OIL

		Sources
Energy of Material Resource	18.0 million Btu	10
Raw Materials		3
Material process additions (chemicals 0.29, cement 1.0, muds 0.59)	1.88 lb	
Energy		47
Electric	6.34 kwhr	
Fuel oil mobile source	0.36 gal.	
Gasoline mobile source	0.08 gal.	
Natural gas internal combustion	0.04 cu ft	
Water Volume	72.0 gal.	47
Solid Wastes	0.60 lb	3
Process Atmospheric Emissions		47
Hydrocarbons	1.4 lb	
Waterborne Wastes		47
Dissolved solids	11.0 lb	
Transportation		47
Barge	28.0 ton-miles	
Truck	10.0 ton-miles	
Pipeline	110.0 ton-miles	

C. Benzene Manufacture

Figure 6 shows an outline for processes typical of refinery treatment of crude oil.[10] The oil enters the refinery and passes through an initial purification step where water soluble salts and some "heavies" are removed. It then is sent to a distillation unit where the components of the crude are separated according to their boiling points. The light gases go overhead to a gas processing plant or serve as process fuels. The other cuts are routed to hydrotreating, cracking, reformer, or other units to undergo the desired transformations.

The benzene needed for styrene manufacture can be produced in a refinery. With reference to Figure 7, the steps for obtaining benzene are: crude distillation, catalytic reforming, and aromatics separation. The toluene from the separation unit can be dealkylated to produce more benzene.[7] Table 35 lists the environmental impacts for production of 1,000 pounds of benzene. Crude oil is the virgin raw material. A material loss of about 3 percent occurs between the point the crude enters the plant and benzene storage.[47] Much of the loss, such as CO_2 and water vapor, is not accounted for in the impact analysis since they are not considered to be critical pollutants. The BOD and COD tests do not reflect the benzene concentration in the wastewater effluent. The 5-day BOD for pure benzene is zero.[53] The solubility of benzene in water is around 0.08 percent. Instrumental methods such as gas chromatography or total organic carbon analysis could be used to determine the amount of organics, when the standard methods are limited in their analytical scope.

D. Natural Gas Production

The basic data for natural gas were taken from the 1967 Census of Mineral Industries.[89] The data pertaining to natural gas production are presented in Table 36. The quantity of production necessary to achieve 1,000 pounds of product gas is counted as its energy equivalent, rather than as pounds of raw materials. Therefore the energy requirement is large but 97.6 percent of this quantity represents the energy equivalent of the natural gas. The second largest impact is atmospheric emissions of hydrocarbons, mainly methane.

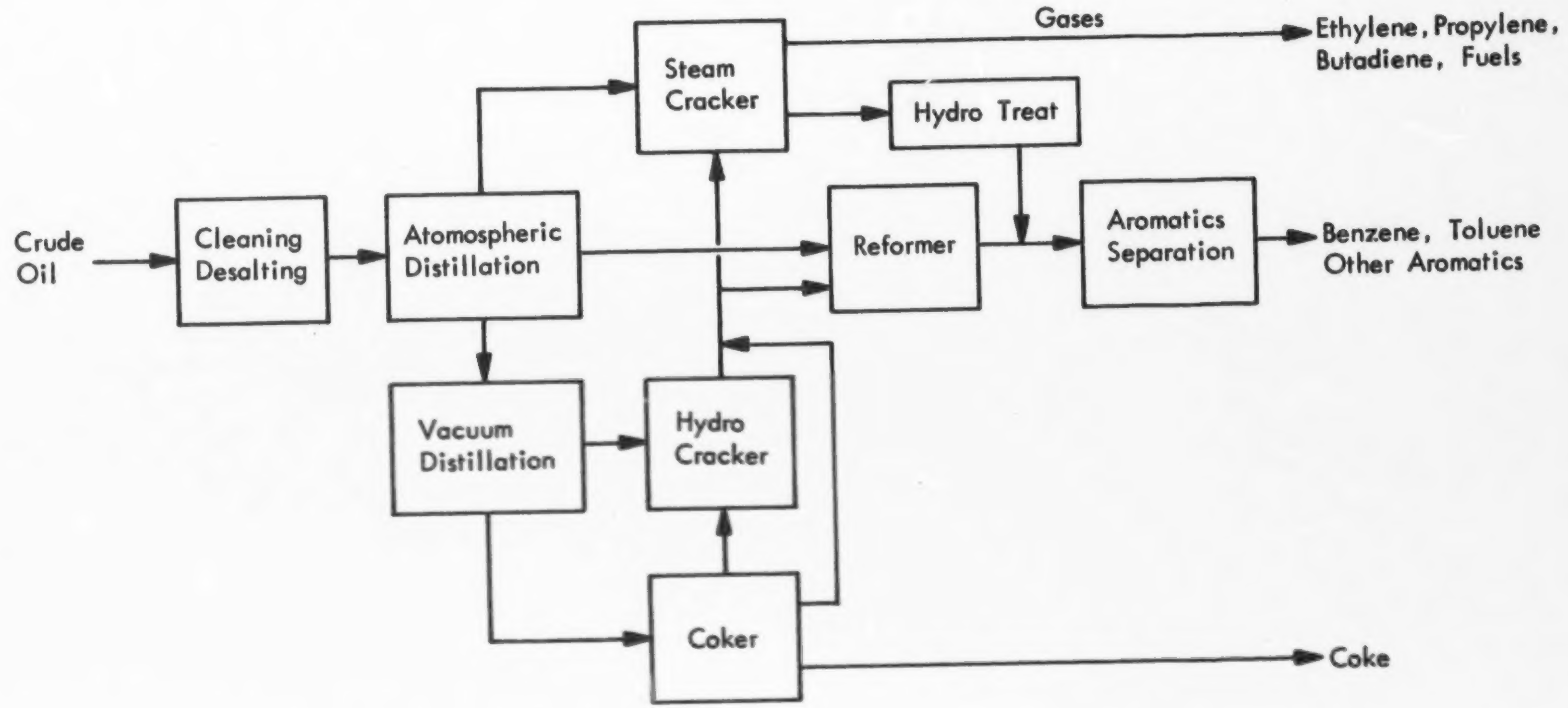

Crude Oil
Cleaning Desalting
Atomospheric Distillation
Vacuum Distillation
Steam Cracker
Hydro Cracker
Coker
Hydro Treat
Reformer
Aromatics Separation
Gases
Ethylene, Propylene, Butadiene, Fuels
Benzene, Toluene Other Aromatics
Coke

Figure 6 - Flow Diagram for Typical Petrochemical Refinery

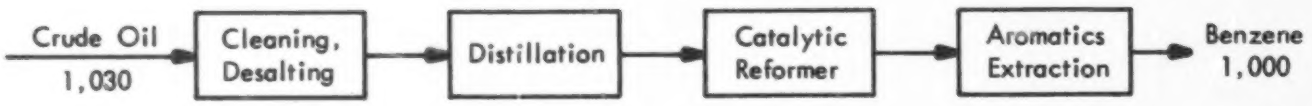

Crude Oil
1,030
Cleaning, Desalting
Distillation
Catalytic Reformer
Aromatics Extraction
Benzene
1,000

Figure 7 - Processes for Manufacture of 1,000 Pounds of Benzene (lb)

TABLE 35

DATA FOR MANUFACTURE OF 1,000 POUNDS OF BENZENE

		Sources
Raw Materials		67
Catalyst	5.0 lb	
Energy		47
Electric	49.0 kwhr	
Natural gas	6,000.0 cu ft	
Water Volume	4,200 gal.	47
Process Solid Wastes	1.0 lb	67
Process Atmospheric Emissions		47,75
Particulates	0.35 lb	
Hydrocarbons	3.10 lb	
Sulfur oxides	3.40 lb	
Aldehydes	0.05 lb	
Other organics	0.05 lb	
Ammonia	0.06 lb	
Waterborne Wastes		21,51,76
BOD	0.035 lb	
COD	0.120 lb	
Oil	0.020 lb	
Suspended solids	0.070 lb	
Sulfides	0.013 lb	
Phenols	0.0097 lb	
Transportation		
Pipeline	3 ton-miles	67
Barge	12 ton-miles	
Truck	15 ton-miles	

TABLE 36

DATA FOR PRODUCTION OF 1,000 POUNDS OF NATURAL GAS

		Sources
Energy of Material Resource	22.391 million Btu[a]	9
Energy		47
Electric	3.8 kwhr	
Fuel oil mobile source	0.28 gal.	
Gasoline mobile source	0.08 gal.	
Natural gas internal combustion	330.0 cu ft	
Water Volume	29.0 gal.	47
Process Atmospheric Emissions		40,44
Hydrocarbons	10.0 lb	
Waterborne Wastes		47
Dissolved solids	3.9	

---

[a] $$\left(1{,}000 \text{ lb NG} \div 0.046 \frac{\text{lb}}{\text{cu ft}}\right) \times 1{,}030 \frac{\text{Btu}}{\text{cu ft}} = 22{,}391 \text{ million Btu}$$

E. Natural Gas Processing

Light straight chain hydrocarbons are normal products of a gas processing plant. The plant uses compression, refrigeration and oil absorption to extract these products.[7] Heavy hydrocarbons are removed first. The remaining components are extracted and kept under controlled conditions, until transported in high pressure pipelines, in insulated railcars or in barges. The primary nonsalable residues coming from the natural gas stream are volatile hydrocarbons leaking into the atmosphere.

Table 37 contains a summary of processing impacts. The large natural gas fueled compressor engines use 92 percent of the process energy attributed to the whole industry, and contribute 80 percent of the air pollution. Table 33 shows that atmospheric emissions are the most important impact.

TABLE 37

DATA FOR PROCESSING 1,000 POUNDS OF NATURAL GAS

		Sources
Energy		47
Electric	9.4 kwhr	
Natural gas	5,200.0 cu ft	
Water Volume	280.0 gal.	47
Process Atmospheric Emissions		40,44
Hydrocarbons	10.0 lb	
Transportation		47
Rail	42 ton-miles	
Truck	14 ton-miles	
Barge	14 ton-miles	
Pipeline	70 ton-miles	

F. Ethylene Manufacture

Ethylene is produced by cracking natural gas liquids, and petroleum feedstocks and as a refinery coproduct. Figure 8 shows a typical ethylene plant flow diagram. The feedstock enters the reactors along with steam to lessen coke formation. The cracked gases are quenched with water and compressed. Carbon dioxide, acetylene and water are removed. The clean dry hydrocarbons are sent to fractionation columns to separate ethylene from by-products and uncracked feedstock.

Data for the environmental impacts of ethylene (olefin) production are presented in Table 38. Most of the energy used in the process is for running large compressors. The water volume used is typical for dehydrogenation and cracking units. Solid wastes from the process are negligible. Process atmospheric emissions are reported to be around 0.1 percent of throughput.

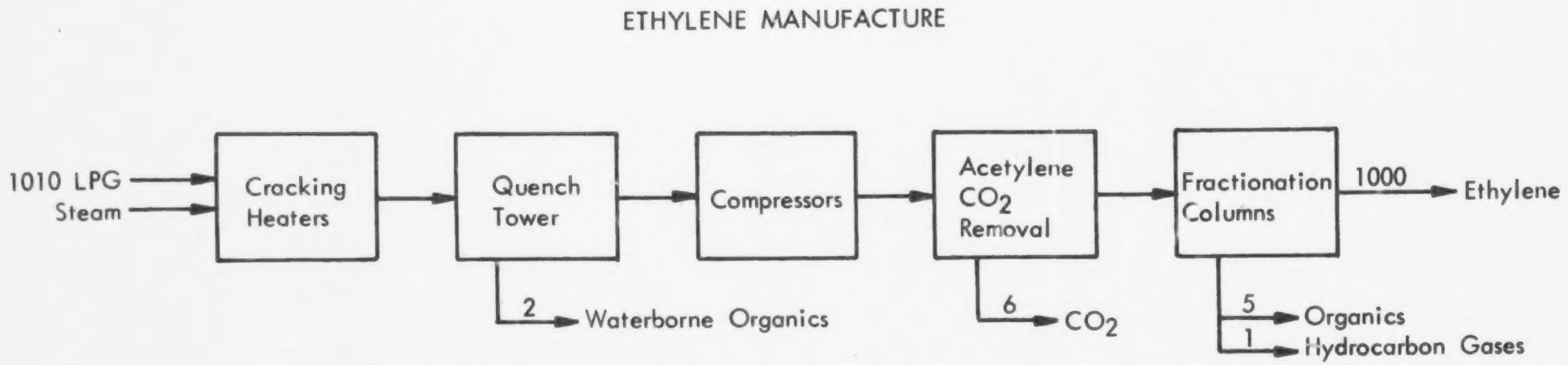

ETHYLENE MANUFACTURE
1010 LPG
Steam
Cracking Heaters
Quench Tower
2
Waterborne Organics
Compressors
Acetylene CO_2 Removal
6
CO_2
Fractionation Columns
1000
Ethylene
5
Organics
1
Hydrocarbon Gases

Figure 8 - The Manufacture of 1,000 Pounds of Ethylene

TABLE 38

DATA FOR MANUFACTURE OF 1,000 POUNDS OF ETHYLENE

		Sources
Raw Materials		
Catalysts	0.2 lb	33
Energy		24,47
Electric	60.0 kwhr	
Natural gas internal combustion	4,950.0 cu ft	
Natural gas industrial heat	1,500.0 cu ft	
Water Volume	1,200.0 gal.	24,76
Process solid wastes	1.00 lb	
Process Atmospheric Emissions		67
Hydrocarbons	1.00 lb	
Waterborne wastes		47
BOD	2.0 lb	
COD	5.2 lb	
Oil	1.8 lb	
Suspended solids	2.9 lb	

G. 1,3-Butadiene Manufacture

The principal commercial routes to butadiene are dehydrogenation of n-butane and n-butenes, and as a by-product during the manufacture of olefins.[73] A typical butane dehydrogenation process is shown in Figure 9. The butanes feed stream is preheated, and passed through the reactor catalyst bed to achieve dehydrogenation. The reaction products are quenched in oil, compressed and scrubbed with absorber oil to remove most of the C_4's. The C_4 mixture is recovered in a stripping column. After further separation, the remaining butadiene is recovered by extractive distillation with furfural. The butadiene rerun tower removes polymer, 2-butene, acetylenes, and 1,2-butadiene. The final product is generally greater than 98.7 percent 1,3 butadiene.

The data for environmental impacts are shown in Table 39 with the resulting impacts in Table 33.

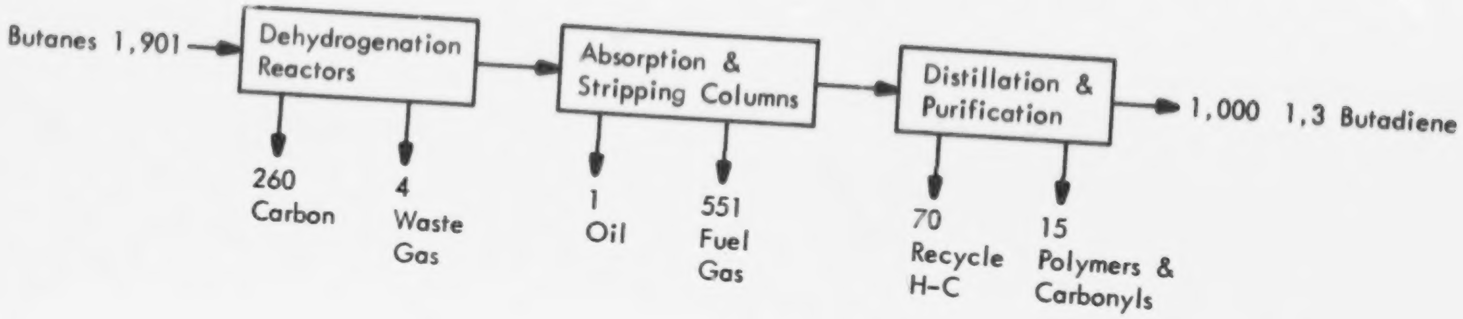

Butanes 1,901
Dehydrogenation Reactors
260 Carbon
4 Waste Gas
Absorption & Stripping Columns
1 Oil
551 Fuel Gas
Distillation & Purification
70 Recycle H-C
15 Polymers & Carbonyls
1,000 1,3 Butadiene

Figure 9 - The Manufacture of 1,000 Pounds of 1,3-Butadiene

TABLE 39

DATA FOR MANUFACTURE OF 1,000 POUNDS OF 1,3 BUTADIENE

		Sources
Raw Materials		67,72
Material process additions	26.0 lb	
Energy		72
Electric	215.0 kwhr	
Natural gas	4,327.0 cu ft	
Water Volume	4,545 gal.	72
Process Solid Wastes	0.74 lb	67,72
Process Atmospheric Emissions		40
Hydrocarbons	1.34 lb	
Waterborne Wastes		67,76
BOD	0.75 lb	
COD	3.29 lb	
Oil	0.05 lb	
Suspended solids	0.20 lb	

The electric and natural gas values are averages derived from combining the energy inputs for three separate methods of production. The tabulation below shows the breakdown for each process.72/ These values have been adjusted to reflect by-product credit.

Process	Percent of Total Production	Total For 1,000 lb of Butadiene		Adjusted for Percent	
		Elec.-kwhr	NG-cu ft	Elec.-kwhr	NG-cu ft
Butanes	30	327	8,656	98.1	2,597
Butenes	47	216	2,684	101.6	1,261
Naphtha	23	67	2,040	15.3	469
Total				215.0	4,327

For the production of 1,000 pounds of butadiene, the energy requirements are calculated to be 215 kwhr of electricity and 4,327 cubic feet of natural gas. This amounts to about 8 million Btu of energy. The large energy requirements for the butanes route is due to the dehydrogenation step.

The process solid wastes were estimated to be 0.1 percent of butadiene production. The solids figure would probably be higher if cuprous ammonium acetate was used to extract butadiene from the C_4 product stream. The solids disposal problem would involve copper salts and spent charcoal, which serves to extract polymers and acetylene compounds from the CAA. Atmospheric hydrocarbon emissions are estimated to be 0.1 percent of the starting raw materials.40/ Waterborne waste data were derived from information describing pollutants from three separate plants located in Texas.

H. Ammonia Manufacture

Ammonia is a colorless gas with a characteristic odor that is perceptible at great dilutions. Its boiling point is -33°C. Ammonia weighs 5.14 pounds per gallon at 60°F, or 38.45 pounds per cubic foot at 60°F.71/ It is prepared on a large scale by direct union of hydrogen and nitrogen: $3H_2 + N_2 = 2NH_3 + 22$ kcal. The percent yield is controlled by temperature, pressure and type of catalyst. Satisfactory conditions for reaction are pressures of 100-200 atmospheres and temperatures of 550°-600°C.9/ A diagram for the production ammonia is presented in Figure 10. Natural gases, or other light hydrocarbons, are steam reformed over a nickel catalyst in a tubular furnace. The hydrocarbons are converted into carbon oxides and hydrogen (generally referred to as synthesis gas). Carbon monoxide is reacted in a shift converter to form carbon dioxide and hydrogen. The carbon dioxide is removed by an absorber, and generally used in the production of urea in an adjacent plant. The absorber off-gas goes through a methanator to convert traces of carbon oxides which would poison the synthesis catalyst. The hydrogen and nitrogen combine in th synthesis loop to form ammonia.

For a typical 1,000 tons per day ammonia plant, 300 gallons of condensate per ton of ammonia are produced.54/ This condensate is either sent directly to a wastewater drain or processed through a stripping tower. A typical untreated condensate will contain the following impurities:

Impurity	Concentration (per 300 gal. of condensate)
NH_3	0.1 lb
NH_4HCO_3	0.1 lb
MEA	0.2 lb

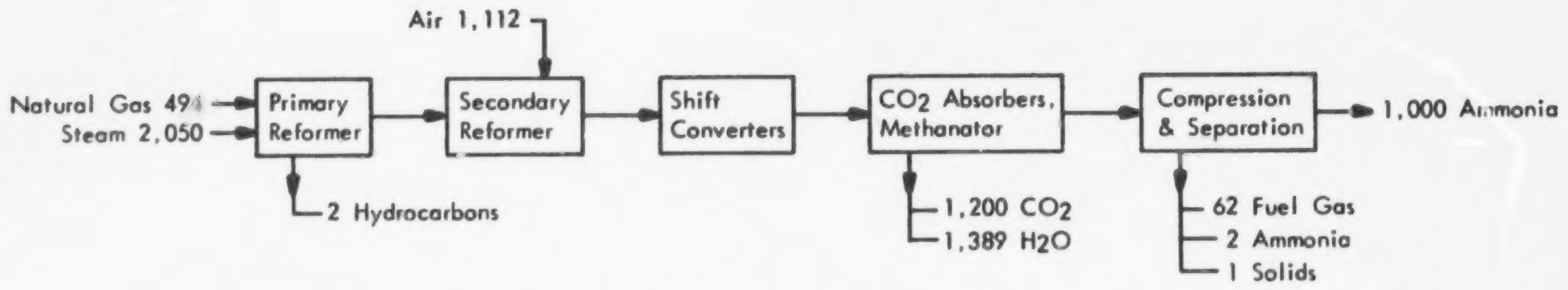

Natural Gas 494
Steam 2,050
Primary Reformer
2 Hydrocarbons
Air 1,112
Secondary Reformer
Shift Converters
CO_2 Absorbers, Methanator
1,200 CO_2
1,389 H_2O
Compression & Separation
62 Fuel Gas
2 Ammonia
1 Solids
1,000 Ammonia

Figure 10 - Process for the Manufacture of 1,000 Pounds of Ammonia (lb)

Treatment in a stripping tower should reduce the NH_3 content to less than 20 parts per million.

The environmental impacts for ammonia production are presented in Table 40. The raw materials, energy, and water volume figures are typical for the industry.[71] Process solid wastes were estimated at 0.1 percent of output.[67] Primary atmospheric emissions were derived from values pertaining to plants without controls. It was assumed that controls are the rule and emissions were reduced by an estimated 90-95 percent.[44] Water effluents from ammonia production contributed the following concentrations of pollutants.[78]

BOD	36 ppm
COD	166 ppm
Oil	40 ppm
Suspended Solids	15 ppm

TABLE 40

DATA FOR MANUFACTURE OF 1,000 POUNDS OF AMMONIA

		Sources
Raw Materials		5
Material Process Additions (Catalyst 0.4, Caustic 4.0, MEA 0.15)	4.55 lb	
Energy		71
Electric	11.0 kwhr	
Natural Gas	3,710.0 cu ft	
Water Volume	3,000.0 gal.	5,76
Process Solid Wastes	0.44 lb	67,71
Process Atmospheric Emissions		44,75
Hydrocarbons	2.00 lb	
Ammonia	2.20 lb	
Waterborne Wastes		67,78
BOD	0.05 lb	
COD	0.23 lb	
Oil	0.05 lb	
Suspended Solids	0.05 lb	
Ammonia	0.50 lb	

The plant used as a primary data source also produced three other products. Ammonia production was 38.6 percent of the total output. Emissions from ammonia production were assumed to be 38.6 percent of the quantities present in the final plant effluent.

I. Acrylonitrile Manufacture

Several methods exist for production of acrylonitrile; these processes are:[13]

1. Reacting acetylene with hydrogen cyanide.

2. Dehydration of ethylene cyanohydrin.

3. Ammonia--propylene ammoxidation.

4. Ammonia--propane ammoxidation.

5. Nitric acid--propylene cyanization.

Methods 3, 4, and 5 are the most common commercial processes.[70] The ammonia-propylene ammoxidation process was used as the data source for acrylonitrile production, due to its extensive commercial use and the availability of reliable data. The reaction follows the equation:

$$CH_2{=}CH{-}CH_3 + NH_3 + 1.5O_2 \longrightarrow CH_2{=}CH{-}C{\equiv}N + 3H_2O.$$

The ammonia-propylene route is shown in Figure 11. Propylene may be obtained from refinery catalytic cracking operations or as a co-product in ethylene manufacture. Ammonia is prepared by steam reforming natural gas.

Excluding steam and air, 1,154 pounds of propylene and 373 pounds of ammonia are required to produce 1,000 pounds of acrylonitrile. Also produced in the process are 50 pounds of hydrogen cyanide, 50 pounds of acetonitrile, 108 pounds of fuel gas, 100 pounds of recycle propylene, and 237 pounds of waste carbon, carbon gases, and hydrocarbons. The amount of "useful" by-products is 23 percent of the total useful output of 1,308 pounds. The following example shows how the materials required to produce the by-products are deducted from the total materials requirements, leaving 879 pounds of propylene and 285 pounds of ammonia allocated to the production of 1,000 pounds of acrylonitrile.

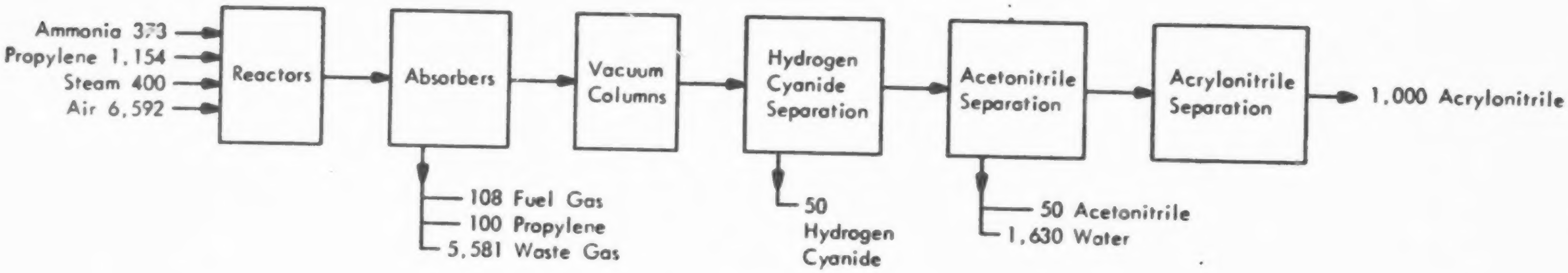

Ammonia 373
Propylene 1,154
Steam 400
Air 6,592
Reactors
Absorbers
108 Fuel Gas
100 Propylene
5,581 Waste Gas
Vacuum Columns
Hydrogen Cyanide Separation
50 Hydrogen Cyanide
Acetonitrile Separation
50 Acetonitrile
1,630 Water
Acrylonitrile Separation
1,000 Acrylonitrile

Figure 11 - The Manufacture of 1,000 Pounds of Acrylonitrile (lb)

Example:

Acrylonitrile Manufacture

	Plant Output	Starting Raw Materials	
Acrylonitrile	1,000	Propylene	1,154
Hydrogen cyanide	50	Ammonia	373
Acetonitrile	50	Total	1,527 lb
Fuel	108		
Propylene	100		
Waste (as carbon)	237		
Total	1,545 lb		

By-products and wastes represent 35.3 percent of the total output $\left(\frac{545}{1,545} \times 100\right)$. The materials required to manufacture the by-products--and wastes attributable to them--can be deducted from the starting raw materials. The waste attributable to the useful by-products equals 23 percent of 237 pounds, or 55 pounds $\left(\frac{308}{1,308} \times 237 = 55 \text{ lb}\right)$. Therefore, the deductions are:

Deductions

Hydrogen cyanide	50
Acetonitrile	50
Fuel	108
Propylene	100
Waste (carbon)	55
	363 lb

The deductions can be accomplished by proportioning the 363 pounds on the basis of quantity of starting raw materials:

$\frac{1,154}{1,527} \times 363 = 275$ lb for propylene deduction

$363 - 275 = 88$ lb for ammonia deduction

leaving:

$1,154 - 275 = 879$ lb propylene

$373 - 88 = 285$ lb ammonia

Since the amount of useful by-products is 23 percent of the usable total output, the requirements for utilities, and allocations for air emissions, and water and solid wastes for acrylonitrile production, can be reduced 23 percent. The values appearing in Table 40 have been adjusted to reflect by-product credit.

Table 41 summarizes the data for the raw impacts attributed to the production of 1,000 pounds of acrylonitrile. The raw materials are considered to be ammonia and propylene. The energy values represent the sum of Btu's from primary and secondary electrical and fuel gas power used to convert ammonia and propylene into acrylonitrile. The water volume represents the amount of water discharged in manufacturing. This figure will vary, depending on the process and location. The process solid wastes have been estimated at 0.1 percent of output, based on literature sources and derived estimates.[67] The process atmospheric wastes are based on the estimate that about 0.5 percent of the incoming hydrocarbons are lost to the atmosphere due to leaks, spills, turnarounds, etc.[40] Waterborne wastes refer to pounds of pollutants present in the process wastewater effluent (not in the water volume required during manufacture). Under present controls, about 10 percent of the manufacturing water volume leaves the plant as wastewater. This ratio will vary widely between companies, processes, and locations.[21] Additional water is lost as a result of evaporation from cooling towers.

The quantity of BOD, COD, etc., in the wastewater stream is dependent upon the efficiency of the plant waste treatment facility.[2,20,32] Generally, waste streams throughout a plant are combined and are treated as one flow.

The amount of contaminants attributable to each process can be calculated if complete data are available for each stream entering the treatment facility, and if the treatment efficiency for each stream is known.[21] Generally, quantitative data for each stream are not available. Most plants report pollutants as the quantity present in their final effluent. The waste treatment facility is designed to reduce total plant contaminants to an acceptable level. State and federal agencies may require that maximum BOD

TABLE 41

DATA FOR MANUFACTURE OF 1,000 POUNDS OF ACRYLONITRILE

		Sources
Raw Materials		70
Material Process Addition (Catalyst 1.5, Oxalic Acid 0.5, Sulfuric Acid 3.5)	5.0 lb	
Energy		70
Electric	70.0 kwhr	
Water Volume	13,800.0 gal.	70
Process Solid Wastes	0.8 lb	67,70
Process Atmospheric Emissions		40, 75
Hydrocarbons	4.40 lb	
Waterborne Wastes		67,76
BOD	3.00 lb	
COD	6.20 lb	
Oil	0.08 lb	
Suspended Solids	0.80 lb	
Cyander	0.0008 lb	
Transportation		67
Rail	400 ton-miles	
Truck	100 ton-miles	

concentrations not be exceeded. An example is 100 milligrams per liter for the plant effluent. If the plant produces 10 different products, the amount of BOD assignable to one of the processes could be allocated on the basis of percentage input and treatment efficiency. If complete data are not available, the amount of BOD contributed by each process generally is estimated from available information. Table 41 shows that water values as well as air and water pollution are important environmental impacts.

J. Styrene Manufacture

A diagram for styrene production is presented in Figure 12.[28] Ethylbenzene and steam react in the presence of a catalyst to form styrene, which is separated from unreacted ethylbenzene, toluene, and polymers by distillation.

Ethylbenzene is commonly made using a Friedel-Crafts type reaction between benzene and ethylene with aluminum chloride as the catalyst. Another catalyst, boron trifluoride-alumina, is also used and results in an overall yield of ethylbenzene of 99 percent from benzene and 93 percent from ethylene.[74]

Table 42 gives the raw impacts for producing styrene. The values are a combination of ethylbenzene and styrene manufacturing impacts.

The process solid wastes are mostly tars and catalyst residues. Atmospheric hydrocarbon emissions were estimated to be 0.6 percent of the raw materials used. Losses occur in leaks, spills, by-product and product loading, etc. By-product credit can be taken for the amounts of benzene and toluene recovered from the process.

K. Polybutadiene Manufacture

Polybutadiene may be manufactured according to the diagram in Figure 13. Butadiene is treated with compounds to remove inhibitors and oxygen. It is then mixed with a solvent and passed through a drying column and solid absorbents to remove water and other catalyst consumers. The purified mixed feed is fed to the reactors, where various terminators, crosslinking agents, modifiers, and catalysts are added. A typical catalyst used for solution polymerization is n-butyllithium. The cement or reactor effluent, is routed to blend tanks where mixing of antioxidants into the polymer solution is effected. The solvent can be removed by several drying methods. Data for polybutadiene manufacture are presented in Table 43.

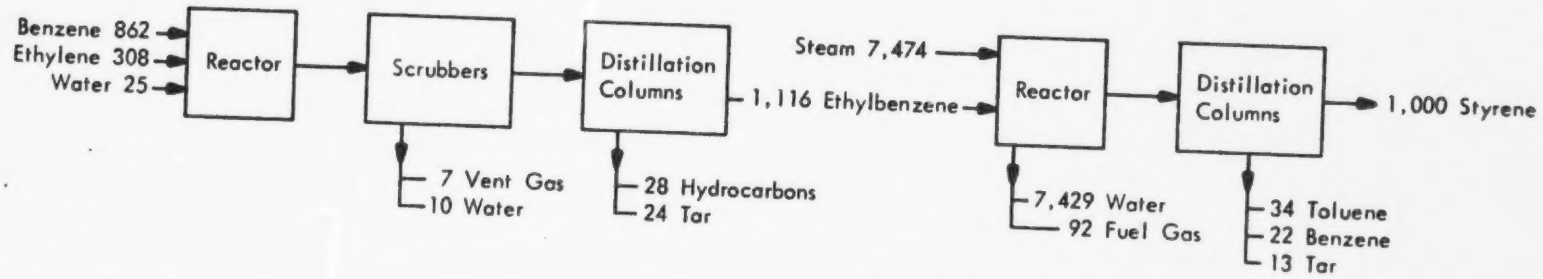

Benzene 862
Ethylene 308
Water 25
Reactor
Scrubbers
7 Vent Gas
10 Water
Distillation Columns
28 Hydrocarbons
24 Tar
1,116 Ethylbenzene
Steam 7,474
Reactor
7,429 Water
92 Fuel Gas
Distillation Columns
34 Toluene
22 Benzene
13 Tar
1,000 Styrene

Figure 12 - The Manufacture of 1,000 Pounds of Styrene

TABLE 42

DATA FOR MANUFACTURE OF 1,000 POUNDS OF STYRENE

		Sources
Raw Materials		
Catalyst	7.4 lb	38
Energy		
Electric	30.0 kwhr	38
Natural gas	4,696.0 cu ft	
Water Volume	11,332.0 gal.	38
Process Solid Wastes	1.0 lb	67
Process Atmospheric Emissions		
Hydrocarbons	5.0 lb	40, 75
Waterborne Wastes		
BOD	2.93 lb	48, 76
COD	7.09 lb	
Oil	0.47 lb	
Suspended solids	2.93 lb	
Transportation		
Rail	400 ton-miles	67
Truck	100 ton-miles	

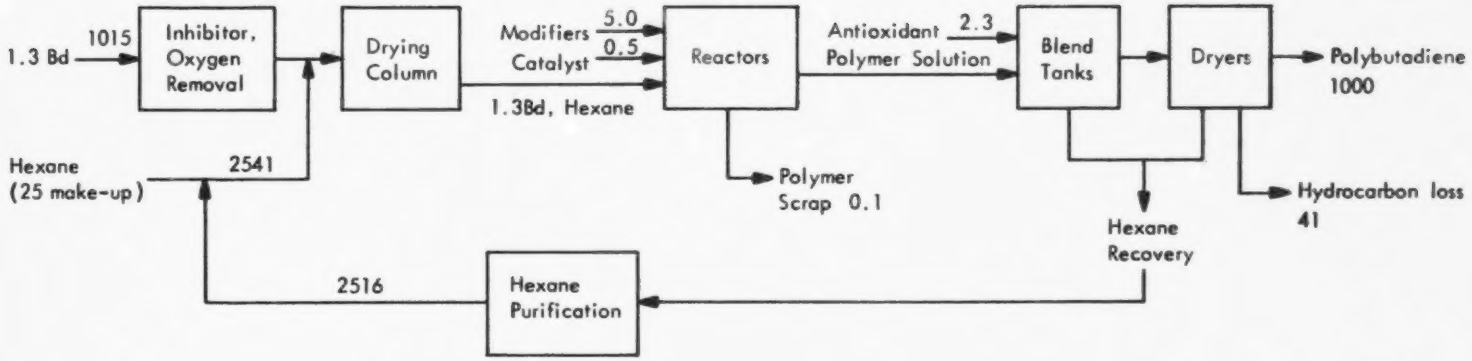

1.3 Bd
1015
Inhibitor, Oxygen Removal
Hexane (25 make-up)
2541
Drying Column
Modifiers 5.0
Catalyst 0.5
1.3Bd, Hexane
Reactors
Polymer Scrap 0.1
Antioxidant 2.3
Polymer Solution
Blend Tanks
Dryers
Polybutadiene 1000
Hydrocarbon loss 41
Hexane Recovery
Hexane Purification
2516

Figure 13 - Manufacture of 1,000 Pounds of Polybutadiene

TABLE 43

DATA FOR MANUFACTURE OF 1,000 POUNDS OF POLYBUTADIENE

		Source
Raw Materials		
Material process additions (solvent 25, catalyst 0.5, modifier 5.0, antioxidant 2.3)	32.8 lb	67
Energy		
Natural gas	2,330.0 cu ft	67
Water Volume	3,330.0 gal.	76
Process Solid Wastes	0.10 lb	67
Process Atmospheric Emissions		
Hydrocarbons	41.0 lb	40, 75
Waterborne Wastes		
BOD	0.41 lb	76
COD	0.83 lb	
Oil	0.07 lb	
Suspended solids	1.25 lb	
Transportation		
Rail	400 ton-miles	67
Truck	100 ton-miles	

The principal contaminant from the process is the hydrocarbon solvent lost to the atmosphere during polymer drying.

L. ABS Resin Manufacture

ABS resins are thermoplastic mixtures generally made by:[69]

1. Copolymerizing styrene with a copolymer of acrylonitrile and butadiene.

2. Blending acrylonitrile-butadiene and acrylonitrile-styrene copolymers.

3. Grafting styrene and acrylonitrile onto a preformed polybutadiene matrix.

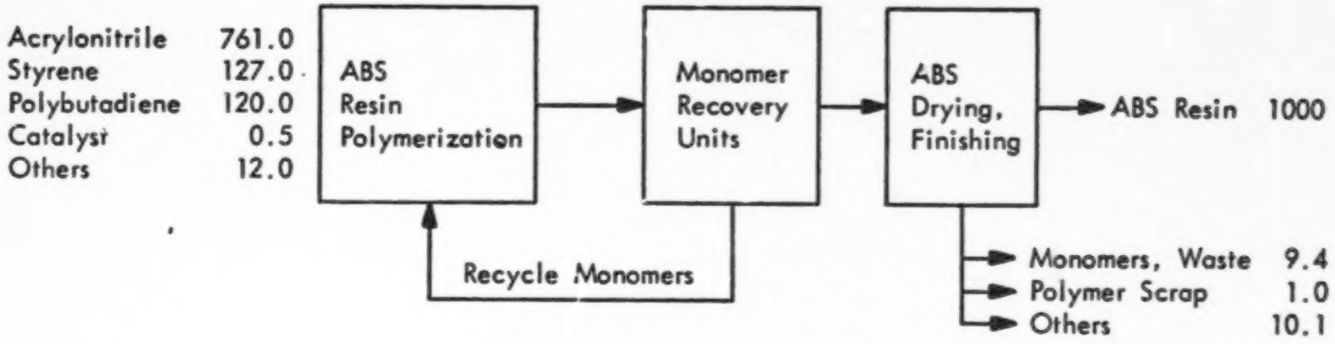
The ABS resins used for beverage containers usually contain about 75 percent acrylonitrile. The exact formulations are generally proprietary. In this report, the quantitative values for input materials and energy, were derived from open literature sources, which describe manufacturing processes similar to the high nitrile barrier resin. The estimates we have used should provide a set of data which will be representative of the various industrial processes used to produce resin for fabrication of barrier bottles.

Figure 14 shows a flow diagram for the manufacture of an ABS resin. We have chosen acrylonitrile, styrene, and polybutadiene as raw materials. (The Barex bottle is a copolymer of acrylonitrile and methyl acrylate, while the Lopac is made from methyacrylonitrile and styrene.)[37]

The data pertaining to manufacturing are shown in Table 44. The energy and water volume data were taken from a process which produces an ABS resin containing 70 percent styrene, 23 percent acrylonitrile and 7 percent polybutadiene.[66] The values should approximate a process producing a high nitrile resin.

The solid waste from manufacturing is estimated to be 0.5 percent of production. Also, incineration is assumed for 80 percent of the wastes, leaving 1 pound as solid wastes.

The atmospheric hydrocarbon losses are estimated to be 0.3 percent of the incoming acrylonitrile and styrene.



Acrylonitrile 761.0
Styrene 127.0
Polybutadiene 120.0
Catalyst 0.5
Others 12.0
ABS Resin Polymerization
Monomer Recovery Units
ABS Drying, Finishing
ABS Resin 1000
Recycle Monomers
Monomers, Waste 9.4
Polymer Scrap 1.0
Others 10.1

Figure 14 - Manufacture of 1,000 Pounds of ABS Resin

TABLE 44

DATA FOR MANUFACTURE OF 1,000 POUNDS OF ABS RESIN

		Sources
Raw materials		
Material process addition (catalysts 0.5, additives 11.5)	12.0 lb	50,67,69
Packaging materials (polyethylene)	20.0 lb	
Energy		
Electric	206.0 kwhr	69
Natural gas	2,386.0 cu ft	
Water volume	2,841.0 gal.	50,69
Process solid wastes	1.0 lb	46,67
Process atmospheric emissions		
Hydrocarbons	2.7 lb	40, 75
Waterborne wastes		
BOD	0.46 lb	50,67
COD	2.36 lb	
Oil	0.02 lb	
Suspended solids	0.49 lb	
Tot chromium	0.0016 lb	
Iron	0.016 lb	
Aluminum	0.016 lb	
Nickel	0.008 lb	
Cyanide	0.0008 lb	
Transportation		
Rail	125 ton-miles	
Truck	125 ton-miles	

Waterborne waste represents the present effluent guidelines set by EPA in March of 1973. The quantities are in close agreement with published data for ABS plant effluents.[50]

M. Bottle Fabrication

The data in Table 45 show the impacts pertaining to fabrication of 12-ounce bottles from an ABS resin. The energy required in the process is the largest impact. The following basic assumptions were made:[31]

1. Basic extrusion line producing 150 lb/hr
2. Electrical requirements - 95 kw
3. Water volume - 1,800 gal. per hour

The requirements for processing 1,000 pounds of resin are: 633 kilowatts and 12,000 gallons of water. The water is assumed to be used five times reducing the make up requirement to 2,400 gallons per 1,000 pounds. The energy requirements will vary with production methods and equipment. Values as low as about 325 kilowatts per 1,000 pounds have been reported.[67]

For a description of bottle filling, refer to Chapter II, section M. The same data used for glass bottles will be used for the ABS bottle. In like manner, Chapter II, section L discusses bottle packaging, Chapter IV, section I describes the steel closure, and Chapter II, section N discusses solids disposal. Impacts for filling, packaging, closures, and solids disposal have been included in the computer printouts.

TABLE 45

DATA FOR FABRICATION OF 1,000 POUNDS OF ABS BOTTLES

		Source
Raw materials		
Material packaging (corrugated)	26.0 lb	31
Energy		
Electric	633.0 kwhr	31
Water volume	2,400.0 gal.	31
Process solid wastes	1.0 lb	67
Transportation	100 ton-miles	67

N. Container Options

The options available to the plastic bottle system are return and recycle. The impacts for a returnable container should approximate those for a glass container described in Chapter II.

Table 46 shows the data pertinent to the manufacture of 1,000 pounds of ABS resin from recycled bottles. The data were derived from the following assumptions:[67]

1. Energy for cleaning and grinding - 50 HP
2. Cleaning compounds - 5 lb
3. Water volume - 100 gal.

TABLE 46

DATA FOR MANUFACTURE OF 1,000 POUNDS OF ABS RESIN FROM RECYCLE MATERIAL

		Source
Raw Materials		
Used bottles	1,053 lb	67
Cleaning compounds	5.0 lb	
Energy		
Electric	37.3 kwhr	67
Water Volume	100.0 gal.	67
Process Solid Wastes	11.0 lb	67
Process Atmospheric Emissions		
Particulates	0.2 lb	67
Waterborne Wastes		
BOD	0.1 lb	
COD	0.2 lb	
Suspended solids	0.2 lb	
Transportation		
Rail	125 ton-miles	67
Truck	125 ton-miles	

The transportation distance was estimated to be 500 miles from consumer disposal to resin plant. Ninety-five percent of the bottles were assumed to be usable as recycle material. Thus, 1,053 pounds of used bottles must be returned to produce 1,000 pounds of resin. Eighty percent of the off-spec material is assumed to be incinerated, leaving 11 pounds as solid wastes.

CHAPTER IV

STEEL CANS

This chapter contains the basic data and outlines the calculations made to determine the total environmental profile for steel beverage cans. Three steel systems were studied. Two of the systems are conventional three-piece steel cans with either aluminum or steel closures. The third system is a hypothetical three-piece steel can made of recycled metal.

Figures 15 and 16 outline the operations which are considered for ferrous strip manufacture. Figure 17 outlines the can fabrication operations. For conventional steel cans there are four major virgin raw materials entering the steel strip system as well as manufactured lime and scrap obtained from outside the steel mill. Thus, counting steel strip manufacture, can fabrication and solvent manufacture, a total of nine operations plus intervening transportation are included. For a hypothetical recycled container, the major material used is postconsumer scrap. Thus, the only operations differing from the conventional system are solid waste processing and electric furnace manufacturing operations.

For analysis of these container systems, this chapter is divided into the following 10 sections. Packaging and disposal basic data are included in Chapter II.

A. Overview of Systems
B. Iron Ore Mining
C. Coal Mining
D. Oxygen Manufacture
E. External Scrap Procurement
F. Steel Strip Manufacture
G. Ferrous Can Fabrication
H. Electric Furnace Steel Manufacture
I. Steel Closures for Cans
J. Can Filling
K. Petroleum Products

A. Overview of Systems

On the following pages is a set of tables numbered 47 through 51. These tables are computer generated reports which provide an overview of the steel can systems. Table 48 summarizes the relative impacts for 1 million, 12-ounce beer cans fabricated from each steel system.

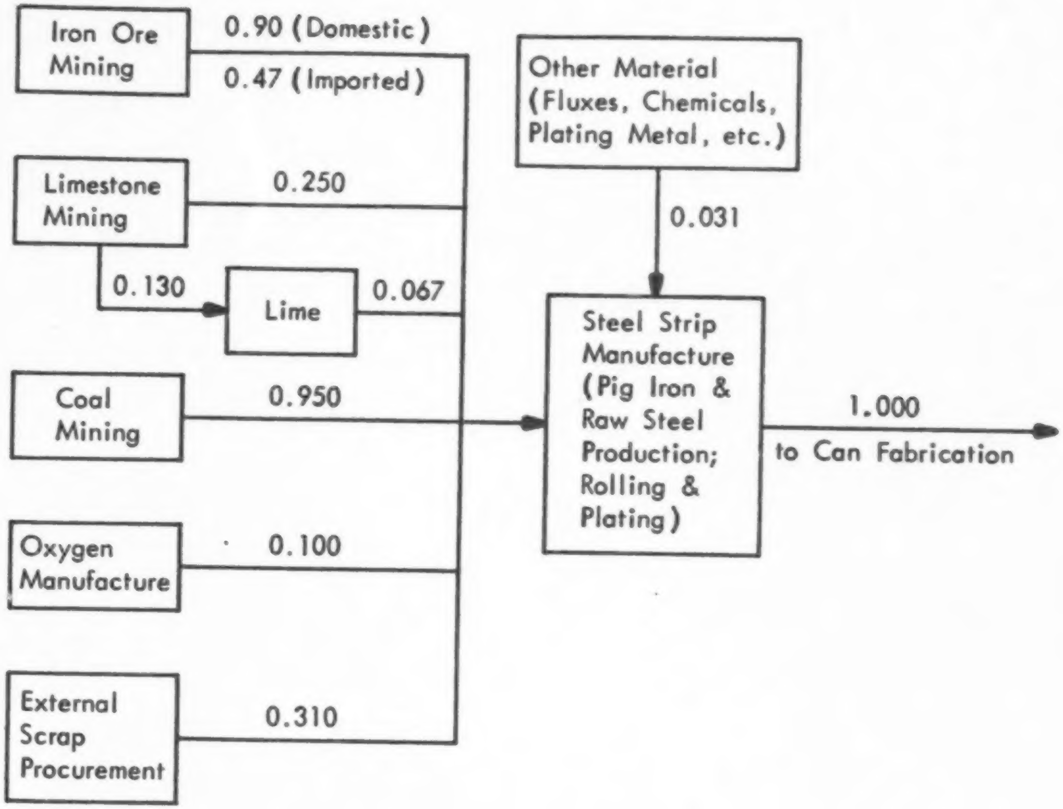

Iron Ore Mining
0.90 (Domestic)
0.47 (Imported)
Limestone Mining
0.250
0.130
Lime
0.067
Coal Mining
0.950
Oxygen Manufacture
0.100
External Scrap Procurement
0.310
Other Material (Fluxes, Chemicals, Plating Metal, etc.)
0.031
Steel Strip Manufacture (Pig Iron & Raw Steel Production; Rolling & Plating)
1.000
to Can Fabrication

Figure 15 - Materials Flow for the Manufacture of One Ton of Steel Strip Using Primarily Virgin Materials (in tons)

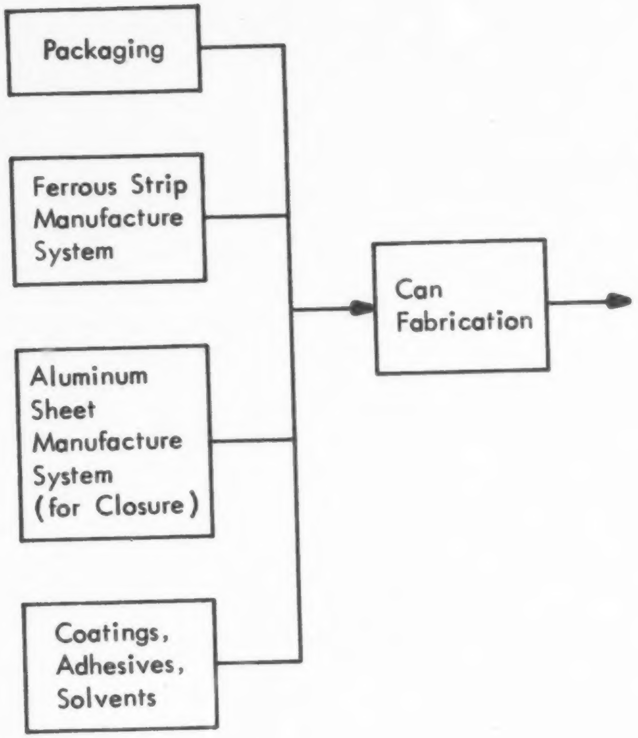

Packaging
Ferrous Strip Manufacture System
Aluminum Sheet Manufacture System (for Closure)
Coatings, Adhesives, Solvents
Can Fabrication

Figure 16

SUMMARY OF MATERIALS REQUIREMENTS FOR STEEL CAN FABRICATION

Materials Requirements for 1-Ton Finished Cans	Bimetal: Cylinder and Bottom	Bimetal: Aluminum Closure	Cylinder and Bottom	Steel Closure
Packaging - lb	50	1.3	48	10
Steel Strip - lb	1,840	--	1,722	378
Aluminum Sheet - lb	--	256	--	--
Coatings and Adhesives				
Solvents - lb	20	10	19	4
Solids - lb	14	9	13	3
Solder - lb	32	--	30	-
Number of Containers/Ton	18,000		16,700	
Weight of 1 Million Containers - Ton	55.4		60.0	

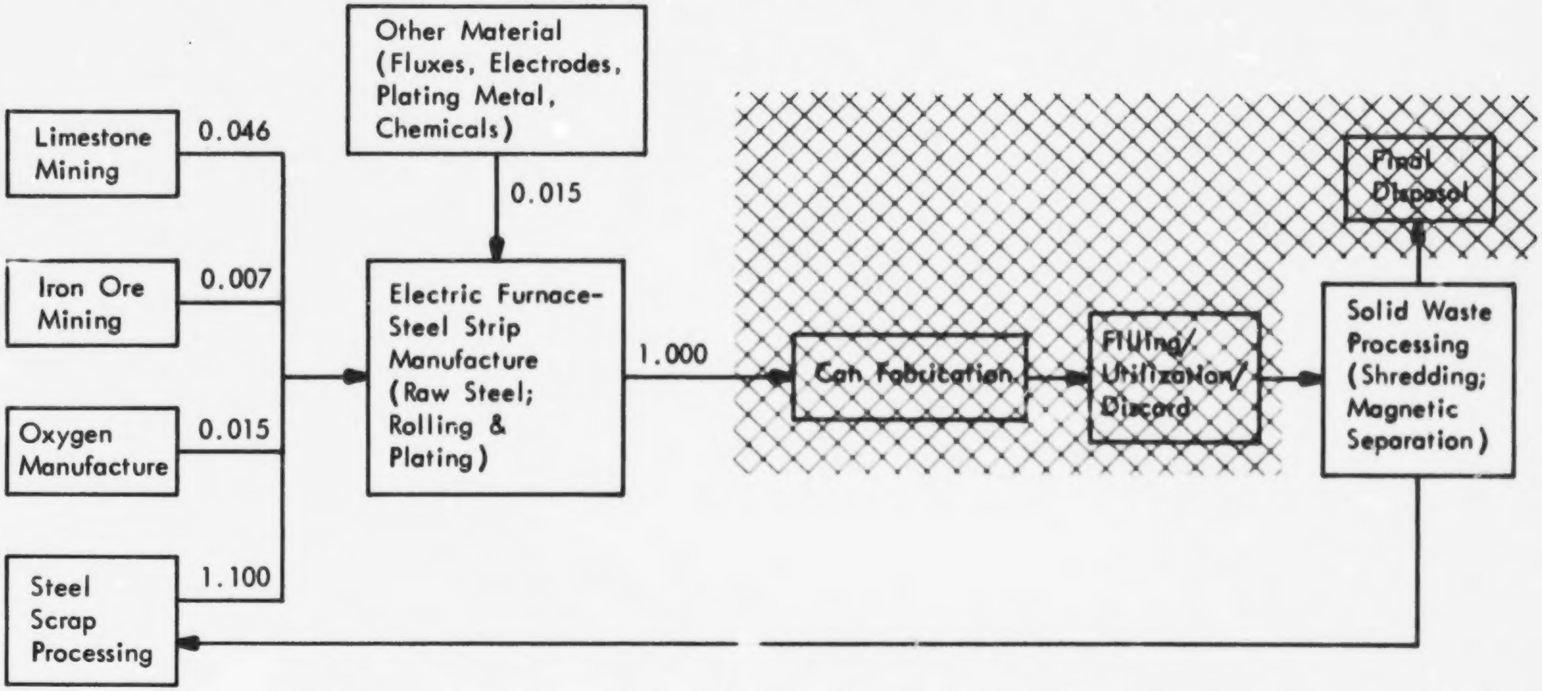

Limestone Mining
0.046
Iron Ore Mining
0.007
Oxygen Manufacture
0.015
Steel Scrap Processing
1.100
Other Material (Fluxes, Electrodes, Plating Metal, Chemicals)
0.015
Electric Furnace-Steel Strip Manufacture (Raw Steel; Rolling & Plating)
1.000
Can Fabrication
Filling/ Utilization/ Discard
Solid Waste Processing (Shredding; Magnetic Separation)
Final Disposal

Figure 17 - Materials Flow for the Manufacture of One Ton of Steel Strip by Melting Scrap in an Electric Furnace (in tons)

TABLE 47

IMPACTS FOR 1 MILLION CANS

INPUT TO SYSTEMS

MATERIALS NAME	UNITS	BIMETAL CAN	ALL STL 100 PCT RECYCLED CAN	ALL STEEL CAN
MATERIAL WOOD FIBER	POUNDS	2703.	2631.	2928.
MATERIAL LIMESTONE	POUND	43021.	10037.	53682.
MATERIAL IRON ORE	POUND	91742.	1045.	124200.
MATERIAL SALT	POUND	3335.	0.	0.
MATERIAL GLASS SAND	POUND	0.	0.	0.
MATERIAL NAT SODA ASH	POUND	0.	0.	0.
MATERIAL FELDSPAR	POUND	0.	0.	0.
MATERIAL BAUXITE ORE	POUND	5957.	0.	0.
MATERIAL PROCESS ADD	POUNDS	10592.	5840.	9483.
ENERGY PROCESS	MIL BTU	4878.	2273.	3631.
ENERGY TRANSPORT	MIL BTU	226.	371.	180.
ENERGY OF MATL RESOURCE	MIL BTU	276.	88.	55.
WATER VOLUME	THOU GAL	3106.	964.	3544.

OUTPUT FROM SYSTEMS

MATERIALS NAME	UNITS	BIMETAL CAN	ALL STL 100 PCT RECYCLED CAN	ALL STEEL CAN
SOLID WASTES PROCESS	POUND	46459.	28213.	56508.
SOLID WASTES FUEL COMB	POUND	9154.	5397.	3464.
SOLID WASTES MINING	POUND	370858.	10748.	434094.
SOLID WASTE POST-CONSUM	CUBIC FT	302.	45.	327.
ATMOS PARTICULATES	POUND	4097.	2363.	3693.
ATMOS NITROGEN OXIDES	POUND	4219.	3062.	2561.
ATMOS HYDROCARBONS	POUND	4671.	4157.	3534.
ATMOS SULFUR OXIDES	POUND	6132.	3200.	3205.
ATMOS CARBON MONOXIDE	POUND	2376.	2481.	1240.
ATMOS ALDEHYDES	POUND	20.	27.	13.
ATMOS OTHER ORGANICS	POUND	18.	19.	12.
ATMOS ODOROUS SULFUR	POUND	124.	29.	162.
ATMOS AMMONIA	POUND	257.	2.	346.
ATMOS HYDROGEN FLOURIDE	POUND	19.	0.	0.
ATMOS LEAD	POUND	1.	3.	0.
ATMOS MERCURY	POUND	0.	0.	0.
ATMOSPHERIC CHLORINE	POUNDS	13.	0.	0.
WATERBORNE FLUORIDES	POUND	79.	0.	0.
WATERBORNE DISS SOLIDS	POUND	693.	522.	384.
WATERBORNE BOD	POUND	111.	60.	74.
WATERBORNE PHENOL	POUND	1.	0.	0.
WATERBORNE SULFIDES	POUND	1.	0.	0.
WATERBORNE OIL	POUND	175.	156.	75.
WATERBORNE COD	POUND	463.	16.	14.
WATERBORNE SUSP SOLIDS	POUND	27510.	1052.	31429.
WATERBORNE ACID	POUND	545.	382.	595.
WATERBORNE METAL ION	POUND	1729.	21.	149.
WATERBORNE CHEMICALS	POUND	152.	3.	4.
WATERBORNE CYANIDE	POUND	0.	0.	0.
WATERBORNE ALKALINITY	POUND	0.	0.	0.
WATERBORNE CHROMIUM	POUND	0.	0.	0.
WATERBORNE IRON	POUND	0.	0.	0.
WATERBORNE ALUMINUM	POUND	0.	0.	0.
WATERBORNE NICKEL	POUND	0.	0.	0.
WATERBORNE MERCURY	POUND	0.	0.	0.
WATERBORNE LEAD	POUND	0.	0.	0.

TABLE 47 (Concluded)

SUMMARY OF SYSTEMS

SUMMARY OF ENVIRONMENTAL IMPACTS NAME	UNITS	BIMETAL CAN	ALL STL 100 PCT RECYCLED CAN	ALL STEEL CAN
RAW MATERIALS	POUNDS	157351.	19554.	190293.
ENERGY	MIL BTU	5380.	2731.	3866.
WATER	THOU GAL	3106.	964.	3544.
INDUSTRIAL SOLID WASTES	CUBIC FT	5757.	599.	6670.
ATM EMMISSIONS	POUNDS	21948.	15342.	14767.
WATERBORNE WASTES	POUNDS	31458.	2213.	32724.
POST-CONSUMER SOL WASTE	CUBIC FT	302.	45.	327.
INDEX OF ENVIRONMENTAL IMPACTS NAME	STANDARD VALUES			
RAW MATERIALS	122394.	129	16	155
ENERGY	3993.	135	68	97
WATER	2538.	122	38	140
INDUSTRIAL SOLID WASTES	4342.	133	14	154
ATM EMMISSIONS	17352.	126	88	85
WATERBORNE WASTES	22132.	142	10	148
POST-CONSUMER SOL WASTE	225.	134	20	146
UNWEIGHTED INDEX		921	254	925
WEIGHTED INDEX OF ENVIRONMENTAL IMPACTS NAME	WEIGHT			
RAW MATERIALS	.05	6	1	8
ENERGY	.40	54	27	39
WATER	.05	6	2	7
INDUSTRIAL SOLID WASTES	.05	7	1	8
ATM EMMISSIONS	.20	25	18	17
WATERBORNE WASTES	.20	28	2	30
POST-CONSUMER SOL WASTE	.05	7	1	7
WEIGHTED COMPOSITE INDEX		133	52	116

TABLE 48

IMPACTS FOR 1 TON OF THE BIMETAL CAN SYSTEM

INPUT TO SYSTEMS

MATERIALS

NAME	UNITS	IRON ORE MINING 1060 LBS	LIMESTON MINING 780 LBS	COAL MINING 1740 LBS	LIME MFG 124 LBS	OXY MFG 102 LBS	EXTERNAL SCRAP 540 LBS	STEEL STRIP MFG 1940 LBS	PETROL PROD SYS 27 LB	3 PIECE CAN FAB 2000 LBS	ALUM CLOSURE SYS 252 LBS	TRANS	DISPOSAL	FILLING 2000 LBS	PAPER PACKAGE 49 LB	PLASTIC PACKAGE 36 LBS
MATERIAL WOOD FIBER	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	48.797	0.000
MATERIAL LIMESTONE	POUND	0.000	0.000	0.000	248.000	0.000	0.000	469.200	0.000	0.000	59.353	0.000	0.000	0.000	0.000	0.000
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	1056.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	68.191	0.000	0.000	0.000	0.000	0.000
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	107.531	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	75.440	.092	82.000	58.020	0.000	0.000	.136	3.444	1.397
ENERGY PROCESS	MIL BTU	.645	.015	.139	.316	.678	.205	37.027	.127	6.420	37.156	0.000	0.000	2.704	.740	.953
ENERGY TRANSPORT	MIL BTU	.049	.011	.038	.002	.009	0.000	.599	.000	0.000	.559	2.430	.119	0.000	.083	0.000
ENERGY OF MATL RESOURCE	MIL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.501	0.000	3.683	0.000	0.000	0.000	0.000	.003
WATER VOLUME	THOU GAL	2.919	.033	.044	.020	.520	.007	42.626	.134	.485	8.383	.140	.008	.050	.720	.040

OUTPUT FROM SYSTEMS

MATERIALS

NAME	UNITS	IRON ORE MINING 1060 LBS	LIMESTON MINING 780 LBS	COAL MINING 1740 LBS	LIME MFG 124 LBS	OXY MFG 102 LBS	EXTERNAL SCRAP 540 LBS	STEEL STRIP MFG 1940 LBS	PETROL PROD SYS 27 LB	3 PIECE CAN FAB 2000 LBS	ALUM CLOSURE SYS 252 LBS	TRANS	DISPOSAL	FILLING 2000 LBS	PAPER PACKAGE 49 LB	PLASTIC PACKAGE 36 LBS
SOLID WASTES PROCESS	POUND	0.000	0.000	0.000	22.638	0.000	0.000	444.000	.017	50.000	65.519	0.000	0.000	54.000	2.204	.178
SOLID WASTES FUEL COMB	POUND	1.361	.042	.511	.102	2.193	.003	23.269	.009	15.034	113.440	.373	.020	2.153	3.113	2.000
SOLID WASTES MINING	POUND	5397.022	.077	331.607	2.271	3.206	1.009	34.417	.133	23.791	885.538	0.000	0.000	9.072	2.018	3.000
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.452	0.000	0.000	0.000
ATMOS PARTICULATES	POUND	10.179	4.558	3.501	2.497	.224	.077	23.968	.026	1.627	23.218	1.039	.016	1.372	1.677	.204
ATMOS NITROGEN OXIDES	POUND	.928	.047	.041	.323	.083	.261	18.193	.100	6.700	37.878	6.100	.165	2.713	.053	2.325
ATMOS HYDROCARBONS	POUND	.623	.018	.008	.173	.396	.152	11.790	.258	28.446	34.679	2.290	.202	1.752	.294	2.394
ATMOS SULFUR OXIDES	POUND	.740	.030	2.279	.699	1.111	.378	25.041	.140	7.901	63.774	1.470	.030	3.981	2.022	1.003
ATMOS CARBON MONOXIDE	POUND	.282	.040	3.957	.109	.233	.062	5.336	.050	1.034	22.363	4.607	1.193	.758	.280	.732
ATMOS ALDEHYDES	POUND	.006	.000	.002	.001	.002	.002	.063	.002	.012	.136	.107	.011	.010	.005	.001
ATMOS OTHER ORGANICS	POUND	.003	.000	.001	.001	.002	.001	.061	.002	.018	.123	.060	.030	.000	.004	.001
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	1.840	0.000	0.000	0.000	0.000	0.000	0.000	.396	0.000
ATMOS AMMONIA	POUND	.000	.000	.000	.000	.000	.000	4.605	.002	0.000	.015	.006	.000	.001	.000	0.000
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.366	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.000	.000	.000	.000	.000	.000	.000	.000	0.000	.009	.007	.003	.000	.000	0.000
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.000	.007	0.000	0.000	.000	.000	.000
ATMOSPHERIC CHLORINE	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.239	0.000	0.000	0.000	0.000	0.000
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.630	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	.127	.007	.027	.029	.072	.052	2.756	.327	.715	6.274	1.167	.063	.451	.124	.253
WATERBORNE BOD	POUND	.000	.000	.000	.000	.000	.000	.004	.001	.001	.745	.003	.030	.001	.997	.245
WATERBORNE PHENOL	POUND	.000	.000	.000	.000	.000	.000	.001	.000	.000	.012	.001	.000	.000	.000	.000
WATERBORNE SULFIDES	POUND	.000	.000	.000	.000	.000	.000	.002	.000	.000	.000	.001	.000	.000	.000	.000
WATERBORNE OIL	POUND	.000	.000	.000	.000	.000	.000	.022	.001	.000	2.130	.002	.030	.000	.000	.105
WATERBORNE COD	POUND	.001	.000	.000	.000	.000	.000	.014	.004	.002	8.102	.012	.001	.002	.001	.210
WATERBORNE SUSP SOLIDS	POUND	415.000	.000	.000	.000	.000	.000	4.689	.002	.002	76.390	.000	.000	.002	.472	.070
WATERBORNE ACID	POUND	.021	.001	3.493	.024	.033	.018	4.031	.001	.241	1.033	.002	.000	.104	.021	.030
WATERBORNE METAL ION	POUND	.005	.000	.073	.006	.000	.003	1.004	.000	.000	29.214	.001	.000	.020	.009	.000
WATERBORNE CHEMICALS	POUND	0.000	0.000	0.000	0.000	0.000	0.000	.055	0.000	0.000	2.685	0.000	0.000	0.000	0.000	0.000
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.001	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE LEAD	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.000	0.000	0.000	0.000	0.000	0.000

TABLE 48 (Concluded)

SUMMARY OF SYSTEMS

		IRON ORE MINING 1440 LBS	LIMESTON MINING 700 LBS	COAL MINING 1740 LBS	LIME MFG 124 LBS	OXY MFG 102 LBS	EXTERNAL SCRAP 580 LBS	STEEL STRIP MFG 1840 LBS	PETROL PROD SYS 27 LB	3 PIECE CAN FAB 2000 LBS	ALUM CLOSURE SYS 252 LBS	TRANS	DISPOSAL	FILLING 2000 LBS	PAPER PACKAGE 49 LB	PLASTIC PACKAGE 30 LBS
SUMMARY OF ENVIRONMENTAL IMPACTS NAME	UNITS															
RAW MATERIALS	POUNDS	0.000	0.000	0.000	240.000	0.000	0.000	2200.660	.052	52.000	285.896	0.300	0.000	.036	49.242	1.397
ENERGY	MIL BTU	.784	.026	.177	.318	.687	.285	38.426	.636	6.420	41.397	2.430	.110	2.704	.823	1.757
WATER	THOU GAL	2.919	.033	.044	.020	.520	.007	42.624	.134	.406	8.383	.140	.000	.050	.720	.048
INDUSTRIAL SOLID WASTES	CUBIC FT	72.878	.002	4.485	.330	.076	.023	9.473	.003	1.209	14.371	.005	.000	.993	.100	.070
ATM EMMISSIONS	POUNDS	12.771	4.695	11.268	3.803	2.651	.932	90.899	.665	46.636	183.791	13.691	1.720	10.544	5.132	6.660
WATERBORNE WASTES	POUNDS	415.154	.008	4.391	.059	.114	.064	13.401	.339	1.022	128.830	1.197	-.064	.500	1.622	.921
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.452	0.000	0.000	0.000
INDEX OF ENVIRONMENTAL IMPACTS NAME	STANDARD VALUES															
RAW MATERIALS	264.026	0	0	0	87	0	0	775	0	18	101	0	0	0	18	0
ENERGY	9.712	8	0	2	3	7	3	396	7	66	426	25	1	28	8	18
WATER	5.607	52	1	1	0	9	0	760	2	7	150	2	0	1	13	1
INDUSTRIAL SOLID WASTES	10.392	701	0	43	3	1	0	91	0	12	138	0	0	9	1	1
ATM EMMISSIONS	39.617	32	12	28	10	7	2	229	2	118	464	35	4	27	13	17
WATERBORNE WASTES	56.784	731	0	8	0	0	0	24	1	2	227	2	0	1	3	2
POST-CONSUMER SOL WASTE	.545	0	0	0	0	0	0	0	0	0	0	0	1000	0	0	0
UNWEIGHTED INDEX		1524	13	82	103	24	5	2275	12	223	1506	64	1005	66	56	39
WEIGHTED INDEX OF ENVIRONMENTAL IMPACTS NAME	WEIGHT															
RAW MATERIALS	.05	0	0	0	4	0	0	39	0	1	5	0	0	0	1	0
ENERGY	.40	3	0	1	1	3	1	158	3	26	170	10	0	11	3	7
WATER	.05	3	0	0	0	0	0	38	0	0	7	0	0	0	1	0
INDUSTRIAL SOLID WASTES	.05	35	0	2	0	0	0	5	0	1	7	0	0	0	0	0
ATM EMMISSIONS	.20	6	2	6	2	1	0	46	0	24	93	7	1	5	3	3
WATERBORNE WASTES	.20	146	0	2	0	0	0	5	0	0	45	0	0	0	1	0
POST-CONSUMER SOL WASTE	.05	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0
WEIGHTED COMPOSITE INDEX		193	2	11	7	4	1	291	3	52	327	17	51	16	9	10

TABLE 49

IMPACTS FOR 1 TON OF THE ALL STEEL CAN SYSTEM

INPUT TO SYSTEMS

MATERIALS NAME	UNITS	IRON ORE MINING 1697 LBS	LIMESTON MINING 717 LBS	COAL MINING 1792 LBS	LIME MFG 126 LBS	OXYGEN MFG 107 LBS	EXTERNAL SCRAP 585 LBS	CLOSURE 360 LBS	STEEL STRIP MFG 1886 LBS	3 PIECE CAN FAB 1886 LBS	TRANS	DISPOSAL 2000 LBS	FILLING CANS 2000 LBS	PAPER PACKAGE 49 LBS	PLASTIC PACKAGE 34 LBS
MATERIAL WOOD FIBER	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	48.797	0.000
MATERIAL LIMESTONE	POUND	0.000	0.000	0.000	252.000	0.000	0.000	161.046	480.930	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	372.600	1697.400	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	26.890	77.326	49.036	0.000	0.000	.034	3.444	1.369
ENERGY PROCESS	MIL BTU	.711	.016	.143	.321	.692	.287	9.319	38.772	6.054	0.000	0.000	2.554	.740	.928
ENERGY TRANSPORT	MIL BTU	.091	.011	.040	.002	.009	0.000	.171	.614	0.000	1.428	.118	.438	.003	0.000
ENERGY OF MATL RESOURCE	MIL BTU	0.000	0.000	0.000	0.000	0.000	0.000	.150	0.000	0.000	0.000	0.000	0.000	0.000	.742
WATER VOLUME	THOU GAL	2.985	.033	.045	.020	.531	.007	10.430	43.690	.383	.002	.000	.073	.720	.046

OUTPUT FROM SYSTEMS

MATERIALS NAME	UNITS	IRON ORE MINING 1697 LBS	LIMESTON MINING 717 LBS	COAL MINING 1792 LBS	LIME MFG 126 LBS	OXYGEN MFG 107 LBS	EXTERNAL SCRAP 585 LBS	CLOSURE 360 LBS	STEEL STRIP MFG 1886 LBS	3 PIECE CAN FAB 1886 LBS	TRANS	DISPOSAL 2000 LBS	FILLING CANS 2000 LBS	PAPER PACKAGE 49 LBS	PLASTIC PACKAGE 34 LBS
SOLID WASTES PROCESS	POUND	0.000	0.000	0.000	22.995	0.000	0.000	150.067	660.100	47.150	0.000	0.000	51.000	2.204	.170
SOLID WASTES FUEL COMB	POUND	1.392	.043	.526	.104	2.241	.087	6.601	23.051	14.931	.217	.020	2.103	3.113	1.952
SOLID WASTES MINING	POUND	5510.617	.079	341.543	2.300	3.358	1.016	1296.009	35.278	22.397	0.000	0.000	9.418	2.010	2.920
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.452	0.000	0.000	0.000
ATMOS PARTICULATES	POUND	10.408	4.662	3.605	2.537	.220	.078	10.151	24.567	1.534	.774	.014	1.315	1.477	.198
ATMOS NITROGEN OXIDES	POUND	.949	.048	.066	.320	.698	.263	6.021	10.640	6.410	1.981	.165	3.459	.653	2.204
ATMOS HYDROCARBONS	POUND	.637	.019	.708	.176	.405	.153	11.706	12.005	26.824	1.270	.202	2.076	.294	2.231
ATMOS SULFUR OXIDES	POUND	.767	.031	2.347	.710	1.135	.380	6.979	25.667	7.451	.998	.030	3.944	2.022	.976
ATMOS CARBON MONOXIDE	POUND	.208	.041	4.074	.111	.230	.063	2.664	5.469	1.730	1.011	1.193	2.005	.200	.713
ATMOS ALDEHYDES	POUND	.006	.000	.002	.001	.002	.002	.018	.065	.012	.063	.011	.020	.005	.001
ATMOS OTHER ORGANICS	POUND	.003	.000	.001	.001	.002	.001	.016	.063	.017	.030	.030	.022	.004	.001
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	.414	1.086	0.000	0.000	0.000	0.000	.396	0.000
ATMOS AMMONIA	POUND	.000	.000	.000	.000	.000	.000	1.037	4.721	0.000	.004	.000	.002	[illegible]	0.000
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.000	.000	.000	.000	.000	.000	.000	.000	0.000	.002	.003	.002	.000	0.000
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	.000	.000	.000	0.000	0.000	0.000	.000	.000	.000
ATMOSPHERIC CHLORINE	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	.129	.007	.028	.029	.073	.053	.032	2.824	.675	.600	.063	.043	.124	.247
WATERBORNE BOD	POUND	.000	.000	.000	.000	.000	.000	.001	.004	.001	.002	.000	.001	.997	.230
WATERBORNE PHENOL	POUND	.000	.000	.000	.000	.000	.000	.000	.001	.000	.001	.000	.000	.000	.000
WATERBORNE SULFIDES	POUND	.000	.000	.000	.000	.000	.000	.001	.002	.000	.001	.000	.001	.000	.000
WATERBORNE OIL	POUND	.000	.000	.000	.000	.000	.000	.208	.945	.000	.001	.000	.001	.000	.102
WATERBORNE COD	POUND	.001	.000	.000	.000	.000	.000	.005	.015	.002	.007	.001	.005	.001	.204
WATERBORNE SUSP SOLIDS	POUND	424.350	.000	.000	.000	.000	.000	94.180	4.724	.001	.005	.000	.003	.472	.060
WATERBORNE ACID	POUND	.021	.001	3.595	.024	.034	.010	1.720	4.132	.227	.001	.000	.099	.021	.030
WATERBORNE METAL ION	POUND	.005	.000	.899	.006	.009	.003	.430	1.033	.057	.000	.000	.025	.005	.007
WATERBORNE CHEMICALS	POUND	0.000	0.000	0.000	0.000	0.000	0.000	.012	.057	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE LEAD	POUND	0.030	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 49 (Concluded)

SUMMARY OF SYSTEMS

		IRON ORE MINING 1697 LBS	LIMESTON MINING 717 LBS	COAL MINING 1792 LBS	LIME MFG 126 LBS	OXYGEN MFG 187 LBS	EXTERNAL SCRAP 585 LBS	CLOSURE 360 LBS	STEEL STRIP MFG 1806 LBS	3 PIECE CAN FAB 1806 LBS	TRANS	DISPOSAL 2000 LBS	FILLING CANS 2000 LBS	PAPER PACKAGE 49 LBS	PLASTIC PACKAGE 34 LBS
SUMMARY OF ENVIRONMENTAL IMPACTS															
NAME	UNITS														
RAW MATERIALS	POUNDS	0.000	0.000	0.000	252.000	0.000	0.000	560.536	2255.656	49.036	0.000	0.000	.034	52.242	1.360
ENERGY	MIL BTU	.801	.027	.182	.324	.702	.287	9.640	39.386	6.054	1.428	.110	2.993	.823	1.710
WATER	THOU GAL	2.985	.033	.045	.020	.531	.007	10.430	43.690	.303	.002	.000	.073	.720	.046
INDUSTRIAL SOLID WASTES	CUBIC FT	74.520	.002	4.610	.343	.076	.023	19.719	9.710	1.140	.003	.000	.044	.100	.068
ATM EMMISSIONS	POUNDS	13.059	4.802	11.602	3.864	2.709	.930	39.007	93.171	43.970	6.949	1.720	12.053	5.132	6.485
WATERBORNE WASTES	POUNDS	424.507	.008	4.522	.060	.117	.067	97.397	13.736	.963	.697	.064	.776	1.622	.097
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.452	0.000	0.000	0.000
INDEX OF ENVIRONMENTAL IMPACTS															
NAME	STANDARD VALUES														
RAW MATERIALS	317.155	0	0	0	79	0	0	177	711	15	0	0	0	16	0
ENERGY	6.443	12	0	3	5	11	4	150	611	94	22	2	46	13	27
WATER	5.906	51	1	1	0	9	0	177	740	6	1	0	1	12	1
INDUSTRIAL SOLID WASTES	11.116	670	0	42	3	1	0	177	87	10	0	0	0	1	1
ATM EMMISSIONS	24.611	53	20	47	16	11	4	158	379	179	28	7	52	21	26
WATERBORNE WASTES	54.541	778	0	8	0	0	0	179	25	2	1	0	1	3	2
POST-CONSUMER SOL WASTE	.545	0	0	0	0	0	0	0	0	0	0	1000	0	0	0
UNWEIGHTED INDEX		1564	21	101	103	32	8	1018	2553	306	52	1009	100	66	57
WEIGHTED INDEX OF ENVIRONMENTAL IMPACTS															
NAME	WEIGHT														
RAW MATERIALS	.05	0	0	0	4	0	0	9	36	1	0	0	0	1	0
ENERGY	.40	5	0	1	2	4	2	60	245	38	9	1	19	5	11
WATER	.05	3	0	0	0	0	0	9	37	0	0	0	0	1	0
INDUSTRIAL SOLID WASTES	.05	34	0	2	0	0	0	9	4	1	0	0	0	0	0
ATM EMMISSIONS	.20	11	4	9	3	2	1	32	76	36	6	1	10	4	5
WATERBORNE WASTES	.20	156	0	2	0	0	0	36	5	0	0	0	0	1	0
POST-CONSUMER SOL WASTE	.05	0	0	0	0	0	0	0	0	0	0	50	0	0	0
WEIGHTED COMPOSITE INDEX		209	4	14	9	6	3	155	403	76	15	52	29	12	16

TABLE 50

IMPACTS FOR 1 TON OF 100 PERCENT RECYCLED ALL STEEL CONTAINERS

INPUT TO SYSTEMS

MATERIALS NAME	UNITS	EXTERNAL SCRAP 1.11 TON	OXYGEN IRON ORE LIME AND LIMESTON	ELECTRIC FURNACE STL STRP 1.24 TON	THREE PC CAN FAB 1.11 TON	PETRO PROD SYSM 30 LB	CLOSURE FAB 0.18 TON	FILLING AND PLAS PACKAGE	PAPER PACKAGE 45 LB	TRANS	DISPOSAL
MATERIAL WOOD FIBER	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	43.057	0.000	0.000
MATERIAL LIMESTONE	POUND	0.000	52.808	114.448	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL IRON ORE	POUND	0.000	0.000	17.416	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	0.000	0.000	24.880	57.720	.058	9.916	1.353	3.259	0.000	0.000
ENERGY PROCESS	MIL BTU	1.040	.107	24.245	7.127	.141	.331	3.455	.689	.271	0.000
ENERGY TRANSPORT	MIL BTU	0.000	.004	0.000	0.000	.009	.042	.438	.004	2.061	.003
ENERGY OF MATL RESOURCE	MIL BTU	0.000	0.000	0.000	0.000	.556	.150	.759	0.000	0.000	0.000
WATER VOLUME	THOU GAL	.075	.118	14.093	.451	.146	.044	.118	.716	.175	.000

OUTPUT FROM SYSTEMS

MATERIALS NAME	UNITS	EXTERNAL SCRAP 1.11 TON	OXYGEN IRON ORE LIME AND LIMESTON	ELECTRIC FURNACE STL STRP 1.24 TON	THREE PC CAN FAB 1.11 TON	PETRO PROD SYSM 30 LB	CLOSURE FAB 0.18 TON	FILLING AND PLAS PACKAGE	PAPER PACKAGE 45 LB	TRANS	DISPOSAL
SOLID WASTES PROCESS	POUND	0.000	4.819	348.320	55.500	.019	0.105	51.165	2.070	0.000	0.000
SOLID WASTES FUEL COMB	POUND	2.612	.402	60.545	17.576	.099	.267	3.996	3.483	.456	.000
SOLID WASTES MINING	POUND	3.863	43.962	90.370	26.364	.148	.400	12.259	1.666	0.000	0.000
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.742
ATMOS PARTICULATES	POUND	.295	1.276	31.401	1.806	.026	.032	1.507	1.525	.764	.000
ATMOS NITROGEN OXIDES	POUND	.999	.156	24.198	7.545	.200	1.234	5.656	.577	5.270	.004
ATMOS HYDROCARBONS	POUND	.581	.110	15.094	31.575	.206	8.593	4.337	.246	4.246	.006
ATMOS SULFUR OXIDES	POUND	1.445	.343	34.134	8.770	.156	.165	4.891	.037	1.294	.001
ATMOS CARBON MONOXIDE	POUND	.238	.070	11.231	2.036	.064	.407	2.696	.250	12.301	.095
ATMOS ALDEHYDES	POUND	.006	.001	.076	.014	.002	.001	.029	.004	.164	.000
ATMOS OTHER ORGANICS	POUND	.003	.001	.068	.020	.002	.001	.024	.003	.009	.014
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.478	0.000	0.000
ATMOS AMMONIA	POUND	.001	.000	.005	0.000	.002	.000	.002	.000	.008	.000
ATMOS HYDROGEN FLUORIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.000	.000	.000	0.000	.000	.000	.002	.000	.025	.000
ATMOS MERCURY	POUND	.000	.000	.001	.000	.000	.000	.000	.000	0.000	0.000
ATMOSPHERIC CHLORINE	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	.201	.020	3.291	.794	.364	.141	.002	.107	1.471	.001
WATERBORNE BOD	POUND	.000	.000	.005	.001	.002	.000	.232	.753	.004	.000
WATERBORNE PHENOL	POUND	.000	.000	.002	.000	.000	.000	.000	.000	.001	.000
WATERBORNE SULFIDES	POUND	.000	.000	.002	.000	.001	.000	.001	.000	.002	.000
WATERBORNE OIL	POUND	.000	.000	2.490	.000	.001	.000	.100	.000	.002	.000
WATERBORNE COD	POUND	.002	.000	.019	.003	.005	.001	.203	.001	.015	.000
WATERBORNE SUSP SOLIDS	POUND	.001	3.301	13.696	.002	.003	.001	.069	.414	.009	.000
WATERBORNE ACID	POUND	.034	.011	5.894	.267	.001	.004	.128	.017	.003	.000
WATERBORNE METAL ION	POUND	.010	.003	.224	.067	.000	.001	.032	.004	.001	.000
WATERBORNE CHEMICALS	POUND	0.000	0.000	.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE LEAD	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 50 (Concluded)

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SUMMARY OF SYSTEMS

		EXTERNAL SCRAP 1.11 TON	OXYGEN IRON ORE LIME AND LIMESTON	ELECTRIC FURNACE STL STRP 1.24 TON	THREE PC CAN FAB 1.11 TON	PETRO PROD SYSM 30 LB	CLOSURE FAB 0.18 TON	FILLING AND PLAS PACKAGE	PAPER PACKAGE 45 LB	TRANS	DISPOSAL
SUMMARY OF ENVIRONMENTAL IMPACTS											
NAME	UNITS										
RAW MATERIALS	POUNDS	0.000	52.808	156.744	57.720	.058	9.916	1.353	47.116	0.000	0.000
ENERGY	MIL BTU	1.090	.192	24.295	7.127	.706	.483	4.652	.773	3.132	.003
WATER	THOU GAL	.025	.118	14.093	.451	.148	.044	.118	.716	.175	.000
INDUSTRIAL SOLID WASTES	CUBIC FT	.087	.664	6.740	1.342	.004	.118	.910	.097	.006	.000
ATM EMMISSIONS	POUNDS	3.567	1.996	116.208	51.766	.739	10.433	19.143	3.930	24.161	.119
WATERBORNE WASTES	POUNDS	.253	3.334	25.679	1.134	.377	.149	1.646	1.317	1.508	.001
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.742
INDEX OF ENVIRONMENTAL IMPACTS											
NAME	STANDARD VALUES										
RAW MATERIALS	32.590	0	162	481	177	0	30	4	145	0	0
ENERGY	4.239	26	5	573	168	17	11	110	18	74	0
WATER	1.589	2	7	887	28	9	3	7	45	11	0
INDUSTRIAL SOLID WASTES	.997	9	67	676	135	0	12	91	10	1	0
ATM EMMISSIONS	23.154	15	9	502	224	3	45	83	17	104	1
WATERBORNE WASTES	3.537	7	94	726	32	11	4	47	37	43	0
POST-CONSUMER SOL WASTE	.074	0	0	0	0	0	0	0	0	0	1000
UNWEIGHTED INDEX		59	344	3845	764	40	105	342	272	233	1001
WEIGHTED INDEX OF ENVIRONMENTAL IMPACTS											
NAME	WEIGHT										
RAW MATERIALS	.05	0	8	24	9	0	2	0	7	0	0
ENERGY	.40	10	2	229	67	7	5	44	7	30	0
WATER	.05	0	0	44	1	0	0	0	2	1	0
INDUSTRIAL SOLID WASTES	.05	0	3	34	7	0	1	5	0	0	0
ATM EMMISSIONS	.20	3	2	100	45	1	9	17	3	21	0
WATERBORNE WASTES	.20	1	19	145	6	2	1	9	7	9	0
POST-CONSUMER SOL WASTE	.05	0	0	0	0	0	0	0	0	0	50
WEIGHTED COMPOSITE INDEX		14	34	576	135	10	18	75	26	61	50

TABLE 51

IMPACTS FOR 1 TON OF EACH PROCESS IN THE STEEL SYSTEMS

INPUT TO SYSTEMS

MATERIALS NAME	UNITS	IRON ORE MINING	COAL MINING	OXYGEN MFG	EXTERNAL SCRAP	STEEL STRIP	3 PIECE CAN FAB	ELECTRIC FURNACE STEEL MAN	STEEL CLOSURE FAB	FILLING MILLION CANS	PETROL PRODUCTS SYSTEM
MATERIAL WOOD FIBER	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL LIMESTONE	POUND	0.000	0.000	0.000	0.000	510.000	0.000	92.000	894.700	0.000	0.000
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	1800.000	0.000	14.000	2070.000	0.000	0.000
MATERIAL SALT	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	0.000	0.000	0.000	0.000	82.000	52.000	20.000	149.387	2.000	3.873
ENERGY PROCESS	MIL BTU	.837	.160	7.445	.982	41.116	6.420	19.530	51.770	153.250	9.427
ENERGY TRANSPORT	MIL BTU	.107	.044	.102	0.000	.651	0.000	0.000	.949	25.787	.580
ENERGY OF MATL RESOURCE	MIL BTU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.834	0.000	37.000
WATER VOLUME	THOU GAL	3.517	.050	5.710	.023	46.330	.406	11.329	57.944	4.298	9.895

MATERIALS NAME	UNITS	IRON ORE MINING	COAL MINING	OXYGEN MFG	EXTERNAL SCRAP	STEEL STRIP	3 PIECE CAN FAB	ELECTRIC FURNACE STEEL MAN	STEEL CLOSURE FAB	FILLING MILLION CANS	PETROL PRODUCTS SYSTEM
SOLID WASTES PROCESS	POUND	0.000	0.000	0.000	0.000	700.000	50.000	240.000	878.151	3000.000	1.236
SOLID WASTES FUEL COMB	POUND	1.640	.587	24.101	2.354	25.293	15.834	48.670	36.671	123.682	6.598
SOLID WASTES MINING	POUND	6502.436	381.250	36.105	3.480	37.410	23.751	72.645	7200.051	554.000	9.836
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS PARTICULATES	POUND	12.264	4.024	2.457	.266	26.052	1.627	25.242	56.397	77.338	1.745
ATMOS NITROGEN OXIDES	POUND	1.118	.966	7.507	.900	19.775	6.798	19.452	33.449	203.500	13.343
ATMOS HYDROCARBONS	POUND	.750	.790	4.352	.524	12.816	28.446	12.134	65.035	122.103	19.099
ATMOS SULFUR OXIDES	POUND	.904	2.619	12.205	1.302	27.219	7.401	27.439	38.774	231.983	10.403
ATMOS CARBON MONOXIDE	POUND	.340	4.548	2.557	.214	5.800	1.834	9.028	14.802	117.928	4.296
ATMOS ALDEHYDES	POUND	.007	.002	.024	.005	.069	.012	.061	.098	1.631	.132
ATMOS OTHER ORGANICS	POUND	.004	.001	.022	.003	.066	.018	.055	.090	1.307	.136
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	0.000	0.000	2.000	0.000	0.000	2.300	0.000	0.000
ATMOS AMMONIA	POUND	.000	.000	.001	.001	5.006	0.000	.004	5.760	.120	.121
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.000	.000	.001	.000	.000	0.000	.000	.000	.125	.001
ATMOS MERCURY	POUND	.000	.000	.000	.000	.000	.000	.000	.000	.003	.000
ATMOSPHERIC CHLORINE	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE FLOURIDES	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	.152	.031	.786	.181	2.995	.715	2.646	4.620	37.802	24.254
WATERBORNE BOD	POUND	.000	.000	.001	.000	.004	.001	.004	.007	.069	.103
WATERBORNE PHENOL	POUND	.000	.000	.000	.000	.001	.000	.001	.002	.024	.028
WATERBORNE SULFIDES	POUND	.000	.000	.001	.000	.002	.000	.002	.003	.031	.036
WATERBORNE OIL	POUND	.000	.000	.001	.000	1.002	.000	2.002	1.154	.034	.060
WATERBORNE COD	POUND	.001	.000	.005	.001	.016	.002	.016	.028	.274	.322
WATERBORNE SUSP SOLIDS	POUND	500.000	.000	.003	.001	5.010	.002	11.010	523.267	.171	.181
WATERBORNE ACID	POUND	.025	4.013	.366	.035	4.381	.241	4.734	9.556	5.812	.100
WATERBORNE METAL ION	POUND	.002	1.003	.042	.009	1.095	.060	.144	2.389	1.453	.025
WATERBORNE CHEMICALS	POUND	0.000	0.000	0.000	0.000	.060	0.000	.040	.069	0.000	0.000
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE LEAD	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 51 (Concluded)

SUMMARY OF SYSTEMS

		IRON ORE MINING	COAL MINING	OXYGEN MFG	EXTERNAL SCRAP	STEEL STRIP	3 PIECE CAN FAB	ELECTRIC FURNACE STEEL MAN	STEEL CLOSURE FAB	FILLING MILLION CANS	PETROL PRODUCTS SYSTEM
SUMMARY OF ENVIRONMENTAL IMPACTS											
NAME	UNITS										
RAW MATERIALS	POUNDS	0.000	0.000	0.000	0.000	2392.000	52.000	126.000	3114.087	2.000	3.873
ENERGY	MIL BTU	.944	.204	7.547	.982	41.767	6.420	19.530	53.554	176.037	47.088
WATER	THOU GAL	3.517	.050	5.710	.023	46.330	.406	11.329	57.944	4.296	9.095
INDUSTRIAL SOLID WASTES	CUBIC FT	87.805	5.155	.813	.079	10.296	1.209	5.418	109.551	49.649	.239
ATM EMMISSIONS	POUNDS	15.387	12.951	29.127	3.214	98.803	46.636	93.415	216.706	756.047	49.276
WATERBORNE WASTES	POUNDS	500.185	5.048	1.254	.228	14.566	1.022	20.642	541.095	45.671	25.110
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
INDEX OF ENVIRONMENTAL IMPACTS											
NAME	STANDARD VALUES										
RAW MATERIALS	569.996	0	0	0	0	420	9	22	547	0	1
ENERGY	35.407	3	1	21	3	118	18	55	151	497	133
WATER	13.950	25	0	41	0	332	3	81	415	31	71
INDUSTRIAL SOLID WASTES	27.021	325	19	3	0	38	4	20	405	184	1
ATM EMMISSIONS	132.156	12	10	22	2	75	35	71	164	572	37
WATERBORNE WASTES	115.442	433	4	1	0	13	1	18	469	40	22
POST-CONSUMER SOL WASTE	0.000	0	0	0	0	0	0	0	0	0	0
UNWEIGHTED INDEX		798	34	88	5	996	70	267	2151	1324	265
WEIGHTED INDEX OF ENVIRONMENTAL IMPACTS											
NAME	WEIGHT										
RAW MATERIALS	.05	0	0	0	0	21	0	1	27	0	0
ENERGY	.40	1	0	8	1	47	7	22	61	199	53
WATER	.05	1	0	2	0	17	0	4	21	2	4
INDUSTRIAL SOLID WASTES	.05	16	1	0	0	2	0	1	20	9	0
ATM EMMISSIONS	.20	2	2	4	0	15	7	14	33	114	7
WATERBORNE WASTES	.20	87	1	0	0	3	0	4	94	8	4
POST-CONSUMER SOL WASTE	.05	0	0	0	0	0	0	0	0	0	0
WEIGHTED COMPOSITE INDEX		107	4	15	1	105	14	46	256	332	68

Table 48 summarizes systems for 1 ton of bimetal (CSTL) cans while Table 49 and 50 summarize the all steel and recycled cans. The remaining Table 51, converts raw data to impacts for 1 ton output of each subsystem. These raw data are presented in tables within the text of this chapter.

Table 47 provides an overview of the relative environmental merits of the two virgin can systems and one 100 percent recycled system. The widely used three-piece bimetal can is clearly the most detrimental to the environment with the highest index. The all steel can is the second most desirable can from an environmental point of view with recycled cans being clearly best.

The first page of Table 47 shows the detailed computer reports of the impacts for 1 million cans and are included here for completeness. Of particular interest is the fact that water pollution from the systems is dominated by suspended solids, acid and metal ion. The acid and metal ion results from acid coal mine drainage. The coal is used either directly, as in steel manufacture, or burned as an energy source. The latter use is predominantly for electrical energy. The other important water pollutant is suspended solids. Values for suspended solids result from the aluminum system, used to calculate the impacts associated with the aluminum pull ring closure used with the bimetal system and for taconite tailings associated with iron ore mining. For the all steel systems, this results from taconite tailings. Thus, the large water pollution impact attributed to steel cans cannot be easily controlled by the can manufacturer or by the ferrous metal producers.

Tables 48 through 50 summarize the systems for 1 ton of cans showing contributions of various component processes. Several observations can be made by viewing these tables. The most important component process for the bimetal system is the aluminum closure. In fact, aluminum accounts for 33 percent of the total impact for the bimetal can system. The most important operation for all steel cans is steel strip manufacture, which accounts for 40 percent of the total.

Most other subprocesses contribute very little in each system, but some major processing step, such as steel manufacture or iron ore mining, is typically the second most abundant source of impacts.

Table 51 shows impacts for 1 ton output of each component process. These tables convert the raw data given in this chapter into impact parameters.

B. Iron Ore Mining

The basic raw material for steel can manufacture is iron ore. This material is found for the most part in flat-lying or gently sloping beds not more than 20 feet thick. Open pit mining accounts for about 90 percent of the iron ore extracted at present, with the remainder being recovered from deep vertical shaft mines.

Because of stringent specifications placed on iron ore used in blast furnaces it is necessary to beneficiate the ore. This requires that the ore be crushed to minus 4 inches and screened to remove minus 1/4-inch pieces. The minus 1/4-inch screenings are concentrated into pellets usually about 3/8 inch to 1/2 inch in diameter by an agglomeration procedure. The agglomeration procedure may take place at either the mine or the steel mill. The crushing and screening operations result in generation of particulate air pollution.

Data concerning the total environmental profile of iron ore mining were derived from government data sources. These are summarized in Table 52. Table 51 is a computer generated table which transforms the data from Table 52, and similar tables for the other operations, into environmental impacts per ton of output for that operation. However, tables, such as 48 is the more meaningful table. It displays the impacts per ton of finished three-piece conventional steel cans.

TABLE 52

DATA FOR MINING OF 1 TON IRON ORE

		Source
Energy		89,90
Natural gas	360 cu ft	
Distillate	0.23 gal.	
Residual	0.43 gal.	
Electric	28 kwhr	
Water Volume	3,500 gal.	90
Mining Wastes	6,500 lb	102
Atmospheric Emissions		
Particulates	12 lb	52
Waterborne Wastes		
Suspended solids (taconite tailings)	500 lb	57,80
Transportation		
Rail	83 ton-miles	84
Water	316 ton-miles	86

Observing Table 52 we see that the dominant environmental effect of mining iron ore is mining wastes. These wastes are quite sizable and amount to 3.25 tons per ton of marketable ore. This impact is largely one of aesthetics, blight and land use. The problem is not so much how to dispose properly of the waste, but the mechanics of disposing of so much waste.

Currently there is much discussion concerning the adverse affects of waterborne disposal of taconite tailings. This method of disposal is alleged to create a serious water pollution problem in Lake Superior. The magnitude of this problem is staggering, as the ore mine which discharges its wastes is reported to dump nearly 22 million long tons a year, amounting to 500 pounds per short ton of the total iron ore mined in this country. The cessation of this problem would significantly improve the profile for virgin steel systems.

Table 48 shows that the overall effect of iron ore mining on three-piece can manufacture is large. On the weighted impact basis 19 percent of the total three-piece can impacts result from iron ore mining, mostly due to the taconite water pollution problems.

C. Coal Mining

The environmental consequences of mining coal are inherently more serious and more difficult to bring under control than those of most mining industries. As opposed to limestone quarries which are located in highly visible locations scattered throughout the country, coal mines tend to be located far from major population regions. Hence, the environmental damage of mining coal has not been as visible as that due to limestone mining.

Coal mining results in many of the same environmental detriments which normally plague limestone mining as well as some which are unique. Those which are common are the dust and noise associated with mining and beneficiation; general unsightliness; improperly disposed solid residues and open surface mines left abandoned in unsatisfactory condition.

In addition, environmental damage results from coal mining in the form of: (1) burning coal refuse banks; (2) acid mine drainage; and (3) mine subsidence. The burning refuse banks are unique to coal mining and are caused by wasted organic material in mine refuse piles undergoing spontaneous combustion. These fires may burn for many years and may require intensive effort over a period of several years to extinguish permanently. Procedures are now established for proper construction of refuse banks which prevent spontaneous combustion, but extinguishing existing fires will be a problem for many years. The air pollution from these fires is included in Table

Acid mine drainage results primarily from the subsidence of layers of material above deep coal mines as abandoned tunnels collapse. Invariably this subsidence ruptures water bearing structures above the mine level and water eventually fills the mine.

This water leaches minerals from the structure through which it moves. The resultant water pollution (shown in Table 53) usually ends up in the local streams and lakes. This problem grows annually and depends not on the rate of coal extraction as do most impacts, but on the cumulative total of coal mined. One source[65/] estimates that to treat acid mine drainage properly to achieve the current water standards of the state of Pennsylvania would require a minimum expenditure of $40 million per year in perpetuity, and this assumes that proper mining techniques are adopted to prevent the problem from growing.

TABLE 53

DATA FOR MINING OF 1 TON COAL

		Source
Energy		89,90
Coal	0.0010 ton	
Distillate	0.22 gal.	
Residual	0.025 gal.	
Natural gas	3.7 cu ft	
Gasoline	0.042 gal.	
Electricity	10 kwhr	
Water Volume		90
Process	46 gal.	65
Mining Wastes	380 lb	41
Atmospheric Emissions		42
Carbon monoxide	4.4 lb	
Sulfur oxide	2.2 lb	
Hydrocarbons	0.7 lb	
Nitrogen oxide	0.7 lb	
Particulates	3.9 lb	52
Waterborne Wastes		65
Sulfuric acid	4 lb	
Iron	1 lb	65,67
Transportation		
Rail	196 ton-miles	84
Water	30 ton-miles	87
Truck	4 ton-miles	67,102

The problem of mine subsidence is important because nearly 5 million acres of land in the U.S. have been undermined by coal production. Included in this total on 158,000 acres of urban lands, often present because of cities whose growth has been stimulated by local coal mining activity. Virtually all of this land will sooner or later be affected adversely by mine subsidence. The magnitude of this problem is reflected in the cost estimates of mine subsidence prevention programs and increased cost of building foundations in potential subsidence areas. The total of these two items is over $1 billion, and this amount represents only a small portion of the total surface damage covered by mine subsidence. Subsidence can be prevented by proper mining techniques, however.

Table 48 shows that coal mining accounts for 1 percent of the weighted impacts of the three-piece bimetal can system. This is due primarily to air pollution.

D. Oxygen Manufacture

The steel industry consumes more oxygen than all other industries combined, using well over one-half of all oxygen produced in this country. Oxygen is used in a variety of iron- and steel-making operations ranging from scrap preparation to basic oxygen process (BOP) steel furnaces. The latter is the most important accounting for 121 billion cubic feet (5 million tons) of oxygen consumption in 1971 which was 58 percent of the total consumed by the steel industry.

Oxygen is manufactured by cryogenic separation of air. This technique is essentially one of liquifying air and then collecting the oxygen by fractionation. The oxygen is produced in the form of a liquid which boils at 300°F below zero at normal atmospheric pressure so that it must be kept under stringent conditions of temperature and pressure for handling. Most oxygen plants are located quite close to their point of consumption to minimize transportation difficulties although there is a small amount of long distance hauling in insulated rail cars.

The environmental data for oxygen manufacture are listed in Table 54. The impacts are in Table 51. The most important impact is energy use. Those of air and water pollution are entirely due to fuel combustion. Table 48 shows that less than 0.5 percent of the can system weighted impacts result from oxygen manufacture.

TABLE 54

DATA FOR MANUFACTURE OF 1 TON OXYGEN

		Source
Energy		
Distillate oil	0.21 gal.	88
Residual oil	0.61 gal.	
Natural gas	1,528 cu ft	
Gasoline	0.49 gal.	
Electricity	415 kwhr	
Water	5,600 gal.	88
Transportation		
Rail	54 ton-miles	82
Truck	13 ton-miles	

E. External Scrap Procurement

The recycling of metallic scrap back into iron and steel furnaces has long been an economically viable means of utilizing ferrous waste materials. For instance, one-half of the metallic input to steel furnaces in 1969 was in the form of scrap. Much of the scrap recovered is generated within the mills themselves and the impacts associated with their recovery are included with normal iron and steel mill operations. However, substantial quantities of scrap are transported to iron and steel mills from external sources (including other mills at different sites). In 1971 this amounted to 2.6 million tons for blast furnace use and 26.8 million tons for use in steel furnaces.

The only environmental damage resulting from scrap procurement is related to energy use for preparing, loading and transporting the scrap. Positive effects of scrap usage on the environment include the displacement of virgin materials (and their related environmental effects) in iron and steel manufacture; and alleviation of solid waste disposal problems by diverting scrap from municipal solid waste streams. At the present time, a rapidly growing but still very small percent of scrap used is derived from municipal waste streams. An optimistic estimate for 1972 places possible steel can recovery from municipal waste at 2.6 billion cans. If each can weighs 0.1 pound, this is approximately 130,000 tons of steel. This amounts to only 0.4 percent of the external scrap used by the steel industry.

The environmental impacts of scrap recovery are not well documented, but they are small as compared to virgin raw material procurement. Table 55 contains data from one installation which magnetically separates ferrous scrap from mixed urban refuse. These data are quite close to MRI estimates of conventional scrap recovery and processing from industrial sources. These data were applied to the recycle options recovering scrap from mixed refuse.

Tables 51 and 48 show the impacts are quite small, accounting for less than 0.5 percent of system totals.

TABLE 55

DATA PERTAINING TO THE PROCUREMENT OF 1 TON SCRAP
(By Magnetic Separation of Mixed Municipal Wastes)

Energy	
Electricity	40 kwhr
Natural gas	190 cu ft
Distillate	1.4 gal.
Transportation	
Rail	130 ton-miles
Truck	2 ton-miles
Barge	20 ton-miles

Source: 67

F. Steel Strip Manufacture

The manufacture of steel strip suitable for can fabrication can be considered to consist of three separate steps: (1) pig iron production, (2) steel production, and (3) rolling and plating. These processes form the basic manufacturing step of converting iron ore into steel and are responsible for most of the environmental impact attributed to can manufacture.

Enormous amounts of energy are required to manufacture steel from raw materials. This energy is primarily supplied by coal which is first coked and then mixed with the raw materials. The energy is consumed in the blast and steel furnaces where the iron ore is converted at high temperatures to iron alloys in a series of chemical reactions with coke, fluxing agents and other materials. The raw steel is then worked into steel strip and is plated with tin or chromium for shipment to can fabricators.

Table 56 shows that iron ore is the leading material input to the steel system. However, in this study we are considering only impacts on the USA, so that depletion of iron ore in foreign countries is not included. Thus, only 0.90 ton of iron ore per ton steel produced was included in the calculations. This represents only the domestic ore used.

Solid wastes in the form of discarded metallics are generated in each step. Most of these materials are recycled directly on-site and, therefore, are not materials which need to be disposed. However, significant solid wastes which require disposal do appear from three sources: (1) fuel combustion residues; (2) wastewater treatment sludges; and (3) slags from iron and steel furnaces. These are listed in Table

For many years a very serious air pollution problem existed for the steel industry from the use of beehive ovens to convert coal into coke. The air pollution problem resulted because approximately 25 percent of the coal was converted to airborne materials which were not subject to any pollution controls.61/ Hence, for every ton of coal input to the plant there were 500 pounds of coal dust, ammonia, odorous sulfides and a variety of other materials emitted into the air. Today, almost all of the beehive ovens have been abandoned in favor of chemical by-product ovens which capture almost all of the effluent for recycling purposes or for conversion to by-products. Other pollution controls to reduce dust and fume emissions from the agglomerating, furnace and finishing areas have also been implemented so that air pollution, although still a problem, is less serious than it was in previous years.

The extent of present air pollution is revealed in Table 51 Air pollution is second only to energy in importance as a weighted impact. It accounts for 16 percent of impacts from steel strip manufacture.

Another serious environmental problem facing the steel industry is water pollution. Waterborne wastes are generated in every subprocess of iron and steel manufacture. These wastes are primarily suspended solids, oils, waste acids, waste plating solutions, and dissolved chemicals. Proper treatment of these wastes is made difficult by the unusually large volumes of effluent streams.

Table 56

DATA FOR THE MANUFACTURE OF 1 TON STEEL STRIP

		Source
Virgin materials		82
Limestone	0.255 tons	
Iron ore[a]	1.37 tons	
Other	0.041 tons	
Total	1.67 tons	
Energy		82
Coal	0.95 tons	
Distillate oil	4.2 gal.	
Residual oil	8.5 gal.	
Tar and pitch	2.0 gal.	
LPG	0.18 gal.	
Natural gas	6,930 cu ft	
Electricity	430 kwhr	
Water volume	46,000 gal.	88
Solid wastes		
Blast furnace slag	220 lb	55,61
Steel furnace slag	340 lb	55,61
Wastewater treatment sludge	140 lb	58,67
Process atmospheric emissions		
Particulates		61
Agglomerating	5 lb	
Coke manufacture	5 lb	
Blast furnace	2 lb	
Steel furnace	9 lb	
Scarfing	2 lb	
Total	23 lb	
Sulfur oxides	11 lb	
Hydrogen sulfide	2 lb	
Ammonia and organics	5 lb	
Waterborne wastes		49,58
Suspended solids	5.0 lb	
Acids	4 lb	
Oil	1.0 lb	
Metal ions	1.0 lb	
Fluorides	0.04	
Other chemicals	0.02	
Transportation		93
Rail	254 ton-miles	
Truck	76 ton-miles	
Water	93 ton-miles	

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[a] About two-thirds (0.90 ton) of the iron ore is domestic.

The primary source of suspended solids is the blast and steel furnace areas. Exit gases from these furnaces are scrubbed to prevent air pollution, and to clean them sufficiently so they may be burned. Some suspended solids are also produced when cleaning the ingots or blooms and during rolling operations.

Waste oils, acids, and plating solutions are produced in the rolling and plating areas. These acids result from cleaning operations, whereas oils and plating solutions result from finishing operations. These solutions typically contain iron salts in addition to other heavy metal ions related to plating operations.

Coke plant wastes generally account for most of the other chemicals found in the waste streams. Coke plant wastes contain phenols as well as ammonia, cyanides, and other chemicals.

Table 48 shows that steel strip manufacture accounts for 29 percent of the weighted impacts. This category is second only to the aluminum closure system in importance as a subprocess of three-piece can manufacture.

G. Ferrous Can Fabrication

Steel strip is shipped to can fabricators to be converted into beer cans. The steel can is made of electrolytic tin plate (ETP) steel or tin-free steel (TFS). These cans are nearly identical except that the TFS can is coated with a very thin layer of chromium instead of tin. This amounts to less than one-half of 1 percent of the final can weight in either case, so the differences are considered negligible.

The three-piece can is fabricated from a metal blank which is soldered or welded to form the can cylinder. A steel bottom and an aluminum top are attached to the can cylinder by mechanical crimping. The connections are made leak-proof with a sealant (end compound). The can is coated and decorated with inks.

Raw data for can fabrication are included in Table 57, with the impacts displayed in Tables 51 and 48.

TABLE 57

DATA FOR FABRICATION OF CAN BODY AND BOTTOM FOR 1 TON OF THREE-PIECE STEEL CANS

		Sources
Virgin materials		67
Solder	32 lb	
Cement, paint, coatings	20 lb	
Solvent	26 lb	
Packaging (corrugated containers)	49 lb	
Energy		67
Natural gas	2,200 cu ft	
Electricity	273 kwhr	
Water volume	320 gal.	88
Solid waste	50 lb	67
Atmospheric emissions		
Process hydrocarbons	24 lb	63
Transportation		93
Rail	97 ton-miles	
Truck	111 ton-miles	
Water	11 ton-miles	

As shown in Table 51 and 48, impacts from can fabrication are important. The composite index shows that can fabrication accounts for 5 percent of the weighted bimetal system impacts. These impacts result from the use of electricity to run plant machinery and natural gas for drying ovens. Significant air pollution also occurs from evaporated solvents of which it is estimated that only 9 percent is incinerated to prevent air pollution.

The most important impacts are energy use and air pollution.

H. Electric Furnace Steel Manufacture

As noted in Section F which describes conventional steel manufacture, large quantities of steel are recycled each year as a normal part of the steel-making process. The scrap is normally high grade industrial waste resulting from metal discarded at various stages in manufacturing. However, the potential exists to obtain much steel from post-consumer ferrous wastes, such as steel cans discarded into municipal waste streams.

In this study we are examining one system which might be used to fabricate ferrous products using post-consumer waste as the primary raw material. This system is the three-piece electric furnace system. Electric furnace technology is well established and presently is being used in many applications. It is typically a small operation compared to large, conventional steel mills. Electric furnaces use scrap as the principal raw material. Most electric furnaces prior to 1960 did not produce carbon steel, but produced various ferroalloys for special purposes. However, in 1971, 71 percent of the output of electric furnaces was carbon steel. These furnaces can produce suitable can steel. Economics dictate the location and choice of output products.

Scrap metal and various additives are charged into an electric furnace through its top. (The materials flow is shown in Figure 17.) These materials are melted by the conversion of electric energy into heat. Current is brought into the furnace through large carbon electrodes and the energy is converted to heat in the furnace. Much less energy is required for this process than for making steel from virgin ore. The electric furnace consumes energy primarily by melting the iron and maintaining a high enough temperature for refining to take place. On the other hand, conventional steel production requires several separate operations: agglomerating, blast furnace operations, and steel furnace operations. The large difference in energy is seen by the fact that an energy requirement of 500 kilowatt-hours per ton of steel for a typical electric furnace translates to a fuel requirement of about 6 million Btu. This quantity may be compared to over 15 million Btu of fuel required for the blast furnace alone to produce 1 ton of pig iron.14/ For 1 ton of steel strip produced, the energy difference is 41 million Btu for conventional steel as opposed to 19 million Btu for the electric furnace system.

The data for electric furnace steel are given in Table 58. The most troublesome on-site impact of electric steel furnaces is air pollution. This results primarily from fume emission. "Fume" is the term applied to electric furnace emissions of airborne particulates--composed predominantly of metal oxides but also of combusted impurities. These particulates are quite small, usually below 2 microns, and are somewhat difficult to control. These emissions occur mainly during charging operations when the roof of the furnace is opened, and during the "boil" phase.

I. Steel Closures for Cans

In the not-too-distant past, steel beverage cans were closed with a steel lid. However, the advent of the aluminum ring pull top has virtually eliminated the steel can closure from the beer can market, although some steel tops still occur on soft drink cans. As environmental aspects of product manufacture become more important, it may be desirable to replace the aluminum tops on steel cans with steel tops.

The steel tops which could be used would probably be fabricated from tin-free steel. The process is a fairly simple one of stamping the lids from sheet blanks. A polymer coating is required which must be dried in an oven.

Table 59 contains the data for the fabrication. The environmental profile is quite similar to that of the can body and bottom fabrication discussed in Section G.

J. Can Filling

Can filling proceeds in a manner similar to that described for bottle filling in Chapter II. The cans are received in the plant, rinsed, filled, and topped with an appropriate closure. Most commonly used is an aluminum ring pull top, although a steel top is used in some cases. The impacts in the filling plant are similar for both aluminum and steel cans, and for beer or soft drink cans. However, for beer a pasteurization is required which is not present in the soft drink system. Also, the kinds of fuels used by brewers are different from those used by soft drink plants. Table 60 summarizes the impact data.

TABLE 58

DATA FOR MANUFACTURE OF 1 TON STEEL STRIP FROM ELECTRIC FURNACE MILLS

		Sources
Materials		39
Scrap	2,140 lb	
Oxygen	30 lb	
Iron ore	14 lb	
Limestone	92 lb	
Carbon electrodes	10 lb	
Plating metal (chromium or tin)	10 lb	
Energy		
Electricity	500 kwhr (furnace)	1
	335 kwhr (rolling and plating)	67
Natural gas	5,400 cu ft	67
Residual oil	10 gal.	67
Water	11,000 gal.	58,67
Process solid wastes	140 lb (slag)	1
	140 lb (treatment sludge)	67
Process atmospheric emissions		
Particulates	20 lb	61
Carbon monoxide	4 lb	61
Waterborne wastes		58,67
Suspended solids	11 lb	
Acids	4 lb	
Oil	2 lb	
Chemicals	0.04 lb	

TABLE 59

DATA FOR FABRICATION OF ONE TON STEEL CAN CLOSURES

Materials	
Steel	2,300 lb
Coatings	
Solids	55 lb
Solvent	45 lb
Paper packaging	5 lb
Energy	
Natural gas	1,000 cu ft
Electricity	23 kwhr
Industrial Solid Wastes	45 lb
Process Atmospheric Emissions	45 lb
Hydrocarbons	
Transportation	
Rail	97 ton-miles
Truck	111 ton-miles
Water	11 ton-miles

Source: 67

Table 48 shows that the impacts of the filling plant are a minor factor in the overall profile, accounting for only 2 percent of the total. Table 48 shows that the most important impacts are energy use and air pollution. The air pollution results from fuel combustion effluents primarily related to the electricity used.

TABLE 60

DATA FOR FILLING 1 MILLION 12-OUNCE CANS

Materials	
Packaging	
Plastic	1,940 lb
Other materials	2 lb
Energy	
Beer	
Coal	1.0 ton
Residual	150 gal.
Natural gas	55,000 cu ft
Electricity	2,000 kwhr
Soft drink	
Natural gas	15,000 cu ft
Electricity	1,700 kwhr
Solid Wastes	3,000 lb
Transportation	
Beer	
Rail	10,000 ton-miles
Truck	7,000 ton-miles
Soft drink	
Truck	125 gal. diesel 400 gal. gasoline

Source: 67

K. Petroleum Products

Various petroleum products are utilized for solvents, petroleum coke and pitch, and for other uses in this study. For those products, a system has been derived using "refinery average" data. These data are summarized in Table 61, and on Table 51. The impacts of this system on the total can systems is quite small.

TABLE 61

DATA FOR 1,000 POUNDS PETROLEUM PRODUCT MANUFACTURE
(Crude Oil Refinery)

		Source
Energy of Material Resource (1,030 pounds crude oil)	18.54 million Btu	10
Energy		47
Electricity	50 kwhr	
Natural gas	3,000 cu ft	
Water	4,800 gal.	47
Atmospheric Emissions		47,75
Particulates	0.35 lb.	
Hydrocarbons	3.1 lb	
Sulfur oxides	3.4 lb	
Aldehydes	0.05 lb	
Other organics	0.05 lb	
Ammonia	0.06 lb	
Waterborne Wastes		21,51,76
BOD	0.051 lb	
Phenol	0.014 lb	
Sulfides	0.018 lb	
Oil	0.03 lb	
COD	0.16 lb	
Suspended solids	0.09 lb	

CHAPTER V

ALUMINUM CANS

The basic data relating to the manufacture of aluminum beer cans are presented in this chapter. The conventional aluminum can system consists of primary rolled and drawn aluminum alloy cans. In addition, four systems using recycled aluminum cans are considered, at recycling levels of 25, 50, 75 and 100 percent.

Figure 17 shows the principal mining and manufacturing processes which are involved in the production of aluminum sheet and the material inputs. Twelve separate operations, including transportation are analyzed. Data relating to crude oil production and refining may be found in Chapter III, and discussions of limestone mining and lime manufacture appear in Chapter II. This chapter is divided into the following eight sections;

A. Overview
B. Bauxite Mining
C. Caustic Soda Manufacture
D. Refining of Alumina
E. Aluminum Smelting
F. Aluminum Rolling
G. Can Fabrication
H. Recycle Options

Filling and distribution of aluminum cans is essentially the same as for steel cans, so those impacts are found in Chapter IV. Waste disposal and packaging data are in Chapter II.

A. Overview

The computer reports for the aluminum can system are presented here. They are of three kinds. Table 62 compares the results for the four recycling options with the conventional system. Table 63 presents the results for 1 ton of conventional aluminum cans. Table 64 summarizes the impacts for 1 ton of each operation.

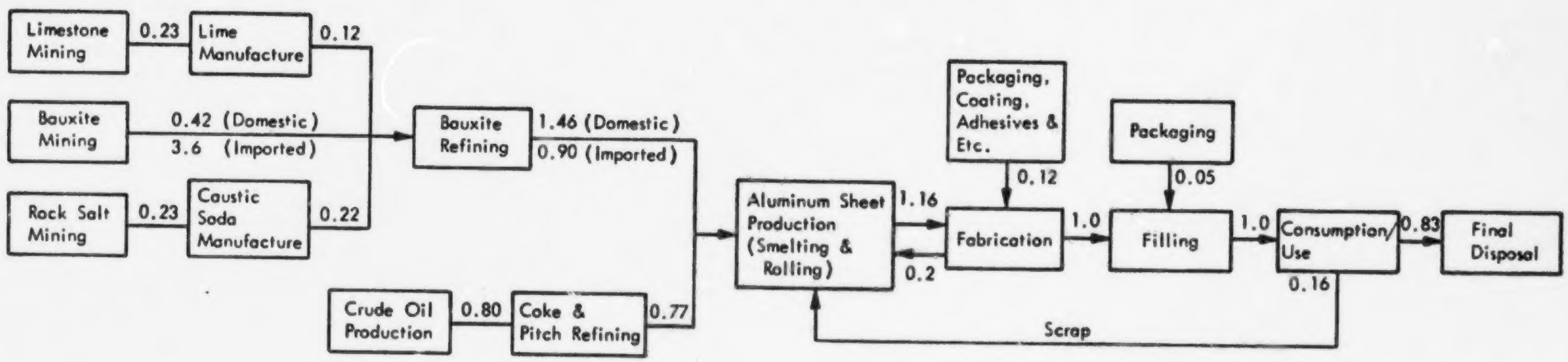
Limestone Mining
0.23
Lime Manufacture
0.12
Bauxite Mining
0.42 (Domestic)
3.6 (Imported)
Rock Salt Mining
0.23
Caustic Soda Manufacture
0.22
Bauxite Refining
1.46 (Domestic)
0.90 (Imported)
Crude Oil Production
0.80
Coke & Pitch Refining
0.77
Aluminum Sheet Production (Smelting & Rolling)
1.16
0.2
Packaging, Coating, Adhesives & Etc.
0.12
Fabrication
1.0
Packaging
0.05
Filling
1.0
Consumption/Use
0.83
Final Disposal
0.16
Scrap

Figure 17 - Materials Flow for 1 Ton Aluminum Cans

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TABLE 62

IMPACTS FOR 1 MILLION CANS EACH ALUMINUM SYSTEM

INPUT TO SYSTEMS

MATERIALS

NAME	UNITS	VIRGIN ALUMINUM	25 PCNT RECYCLE ALUMINUM	50 PCNT RECYCLE ALUMINUM	75 PCNT RECYCLE ALUMINUM	100 PCNT RECYCLE ALUMINUM
MATERIAL WOOD FIBER	POUNDS	2699.	2699.	2699.	2699.	2699.
MATERIAL LIMESTONE	POUND	10752.	6227.	4157.	2079.	0.
MATERIAL IRON ORE	POUND	0.	0.	0.	0.	0.
MATERIAL SALT	POUND	10892.	6333.	4222.	2111.	0.
MATERIAL GLASS SAND	POUND	0.	0.	0.	0.	0.
MATERIAL NAT SODA ASH	POUND	0.	0.	0.	0.	0.
MATERIAL FELDSPAR	POUND	0.	0.	0.	0.	0.
MATERIAL BAUXITE ORE	POUND	19286.	11546.	7522.	3754.	0.
MATERIAL PROCESS ADD	POUNDS	10573.	8144.	7017.	5953.	4893.
ENERGY PROCESS	MIL BTU	7703.	5250.	4095.	2951.	1811.
ENERGY TRANSPORT	MIL BTU	210.	176.	141.	106.	72.
ENERGY OF MATL RESOURCE	MIL BTU	610..	536.	410.	284.	158.
WATER VOLUME	THOU GAL	1546.	1130.	911.	693.	475.

OUTPUT FROM SYSTEMS

MATERIALS

NAME	UNITS	VIRGIN ALUMINUM	25 PCNT RECYCLE ALUMINUM	50 PCNT RECYCLE ALUMINUM	75 PCNT RECYCLE ALUMINUM	100 PCNT RECYCLE ALUMINUM
SOLID WASTES PROCESS	POUND	15303.	12992.	11943.	10893.	9847.
SOLID WASTES FUEL COMB	POUND	22441.	14464.	10730.	7014.	3315.
SOLID WASTES MINING	POUND	162186.	98694.	66339.	35704.	5179.
SOLID WASTE POST-CONSUM	CUBIC FT	298.	232.	166.	100.	34.
ATMOS PARTICULATES	POUND	4581.	2984.	2239.	1510.	785.
ATMOS NITROGEN OXIDES	POUND	8107.	5664.	4481.	3309.	2141.
ATMOS HYDROCARBONS	POUND	5909.	4503.	3798.	3098.	2401.
ATMOS SULFUR OXIDES	POUND	12745.	8281.	6155.	4047.	1949.
ATMOS CARBON MONOXIDE	POUND	4186.	2780.	2091.	1404.	720.
ATMOS ALDEHYDES	POUND	28.	20.	16.	12.	7.
ATMOS OTHER ORGANICS	POUND	29.	22.	18.	14.	9.
ATMOS ODOROUS SULFUR	POUND	22.	22.	22.	22.	22.
ATMOS AMMONIA	POUND	3.	2.	2.	1.	1.
ATMOS HYDROGEN FLOURIDE	POUND	62.	36.	24.	12.	0.
ATMOS LEAD	POUND	0.	0.	0.	0.	0.
ATMOS MERCURY	POUND	0.	0.	0.	0.	0.
ATMOSPHERIC CHLORINE	POUNDS	43.	25.	17.	8.	0.
WATERBORNE FLUORIDES	POUND	256.	150.	100.	50.	0.
WATERBORNE DISS SOLIDS	POUND	1254.	954.	756.	556.	355.
WATERBORNE BOD	POUND	202.	148.	121.	95.	69.
WATERBORNE PHENOL	POUND	2.	1.	1.	1.	0.
WATERBORNE SULFIDES	POUND	1.	1.	1.	0.	0.
WATERBORNE OIL	POUND	385.	372.	365.	359.	352.
WATERBORNE COD	POUND	1465.	882.	580.	297.	14.
WATERBORNE SUSP SOLIDS	POUND	13731.	8312.	5501.	2867.	242.
WATERBORNE ACID	POUND	363.	234.	173.	113.	53.
WATERBORNE METAL ION	POUND	5248.	3146.	2055.	1032.	13.
WATERBORNE CHEMICALS	POUND	481.	319.	235.	157.	79.
WATERBORNE CYANIDE	POUND	0.	0.	0.	0.	0.
WATERBORNE ALKALINITY	POUND	0.	0.	0.	0.	0.
WATERBORNE CHROMIUM	POUND	0.	0.	0.	0.	0.
WATERBORNE IRON	POUND	0.	0.	0.	0.	0.
WATERBORNE ALUMINUM	POUND	0.	0.	0.	0.	0.
WATERBORNE NICKEL	POUND	0.	0.	0.	0.	0.
WATERBORNE MERCURY	POUND	0.	0.	0.	0.	0.
WATERBORNE LEAD	POUND	0.	0.	0.	0.	0.

TABLE 62 (Concluded)

SUMMARY OF SYSTEMS

		VIRGIN ALUMINUM	25 PCNT RECYCLE ALUMINUM	50 PCNT RECYCLE ALUMINUM	75 PCNT RECYCLE ALUMINUM	100 PCNT RECYCLE ALUMINUM
SUMMARY OF ENVIRONMENTAL IMPACTS						
NAME	UNITS					
RAW MATERIALS	POUNDS	54202.	34950.	25617.	16596.	7592.
ENERGY	MIL BTU	8523.	5962.	4646.	3341.	2041.
WATER	THOU GAL	1546.	1130.	911.	693.	475.
INDUSTRIAL SOLID WASTES	CUBIC FT	2699.	1703.	1202.	724.	248.
ATM EMMISSIONS	POUNDS	35716.	24340.	18862.	13436.	8035.
WATERBORNE WASTES	POUNDS	23388.	14524.	9889.	5526.	1178.
POST-CONSUMER SOL WASTE	CUBIC FT	298.	232.	166.	100.	34.
INDEX OF ENVIRONMENTAL IMPACTS						
NAME	STANDARD VALUES					
RAW MATERIALS	27791.	195	126	92	60	27
ENERGY	4903.	174	122	95	68	42
WATER	951.	163	119	96	73	50
INDUSTRIAL SOLID WASTES	1315.	205	130	91	55	19
ATM EMMISSIONS	20078.	178	121	94	67	40
WATERBORNE WASTES	10901.	215	133	91	51	11
POST-CONSUMER SOL WASTE	166.	180	140	100	60	20
UNWEIGHTED INDEX		1310	891	659	434	209
WEIGHTED INDEX OF ENVIRONMENTAL IMPACTS						
NAME	WEIGHT					
RAW MATERIALS	.05	10	6	5	3	1
ENERGY	.40	70	49	38	27	17
WATER	.05	8	6	5	4	2
INDUSTRIAL SOLID WASTES	.05	10	6	5	3	1
ATM EMMISSIONS	.20	36	24	19	13	8
WATERBORNE WASTES	.20	43	27	18	10	2
POST-CONSUMER SOL WASTE	.05	9	7	5	3	1
WEIGHTED COMPOSITE INDEX		186	125	95	63	32

TABLE 63

IMPACTS FOR 1 TON OF ALUMINUM CONTAINERS

INPUT TO SYSTEMS

MATERIALS

NAME	UNITS	BAUXTE MINING 868 LB	CUSTIC SODA SYSTEM 352 LB	LIME SYSTEM 240 LB	PETRO PRODUCTS 680 LB	BAUXITE REFINING 3000 LB	ALUMINUM SMELTING 2120 LB	ALUMINUM ROLLING 2380 LB	AL CLOSE FABRICA 454 LB	AL CAN BODY FARICA 1460 LB	CAN FILLING AND PLAS CARRIER	PAPER PACKAGIN 121 LB	TRANSPOR	DISPOSAL
MATERIAL WOOD FIBER	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	120.500	0.000	0.000
MATERIAL LIMESTONE	POUND	0.000	0.000	480.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	0.000	486.234	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	0.000	0.000	861.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL PROCESS ADD	POUNDS	0.000	7.275	0.000	2.634	210.000	74.200	92.276	22.302	51.246	3.582	8.506	0.000	0.000
ENERGY PROCESS	MIL BTU	.242	4.805	.622	6.410	34.362	230.380	16.862	.653	38.538	9.145	1.828	0.000	0.000
ENERGY TRANSPORT	MIL BTU	.012	.005	.012	.174	0.000	0.000	0.000	0.000	0.000	1.160	.205	7.714	.106
ENERGY OF MATL RESOURCE	MIL BTU	0.000	0.000	0.000	25.214	0.000	0.000	0.000	0.000	0.000	2.008	0.000	0.000	0.000
WATER VOLUME	THOU GAL	.012	1.766	.061	6.722	1.314	39.975	15.685	.009	.928	.313	1.798	.435	.007

OUTPUT FROM SYSTEMS

MATERIALS

NAME	UNITS	BAUXTE MINING 868 LB	CUSTIC SODA SYSTEM 352 LB	LIME SYSTEM 240 LB	PETRO PRODUCTS 680 LB	BAUXITE REFINING 3000 LB	ALUMINUM SMELTING 2120 LB	ALUMINUM ROLLING 2380 LB	AL CLOSE FABRICA 454 LB	AL CAN BODY FARICA 1460 LB	CAN FILLING AND PLAS CARRIER	PAPER PACKAGIN 121 LB	TRANSPOR	DISPOSAL
SOLID WASTES PROCESS	POUND	0.000	5.464	43.800	.840	0.000	285.640	253.700	3.510	29.200	135.436	5.591	0.000	0.000
SOLID WASTES FUEL COMB	POUND	.181	21.526	.227	4.474	61.575	786.991	26.486	1.331	79.599	10.578	7.687	1.154	.018
SOLID WASTES MINING	POUND	.265	95.926	4.449	6.689	5754.150	1180.416	39.729	1.997	119.399	32.449	4.983	0.000	0.000
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	13.301
ATMOS PARTICULATES	POUND	2.933	2.141	7.958	1.131	55.374	111.609	3.542	.139	8.301	3.990	3.647	3.731	.013
ATMOS NITROGEN OXIDES	POUND	.352	4.231	.658	8.258	32.529	225.662	19.197	.716	42.176	14.971	1.613	11.423	.148
ATMOS HYDROCARBONS	POUND	.295	1.802	.347	12.670	18.264	129.083	14.066	24.256	43.583	11.479	.727	6.974	.254
ATMOS SULFUR OXIDES	POUND	.110	10.687	1.373	7.014	61.183	411.794	13.308	.666	39.813	12.946	4.994	5.070	.027
ATMOS CARBON MONOXIDE	POUND	.201	1.023	.239	2.533	8.785	137.214	5.370	.197	11.576	7.137	.692	10.615	1.281
ATMOS ALDEHYDES	POUND	.002	.011	.001	.085	.124	.483	.030	.001	.071	.076	.012	.327	.010
ATMOS OTHER ORGANICS	POUND	.001	.010	.002	.091	.091	.579	.054	.002	.116	.062	.009	.211	.066
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.978	0.000	0.000
ATMOS AMMONIA	POUND	.000	.000	.000	.082	.011	.001	0.000	0.000	0.000	.006	.001	.019	.000
ATMOS HYDROGEN FLUORIDE	POUND	0.000	0.000	0.000	0.000	0.000	2.767	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS LEAD	POUND	.000	.000	.000	.000	.000	.000	0.000	0.000	0.000	.006	.000	.013	.002
ATMOS MERCURY	POUND	.000	.004	.000	.000	.001	.007	.000	.000	.001	.000	.000	0.000	0.000
ATMOSPHERIC CHLORINE	POUNDS	0.000	1.929	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE FLUORIDES	POUND	0.000	0.000	0.000	0.000	.733	10.706	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE DISS SOLIDS	POUND	.053	.416	.061	16.430	4.782	20.973	2.209	.079	4.632	2.335	.307	3.634	.056
WATERBORNE BOD	POUND	.000	.001	.000	.070	2.468	3.402	.001	.000	.003	.614	2.463	.018	.000
WATERBORNE PHENOL	POUND	.000	.000	.000	.019	.056	.011	.000	.000	.001	.001	.000	.003	.000
WATERBORNE SULFIDES	POUND	.000	.000	.000	.025	-.004	.014	.000	.000	.001	.001	.000	.004	.000
WATERBORNE OIL	POUND	.000	.000	.000	.041	.109	1.298	15.459	.000	.002	.244	.000	.005	.000
WATERBORNE COD	POUND	.000	.003	.000	.219	59.732	4.852	.004	.000	.012	.537	.003	.038	.001
WATERBORNE SUSP SOLIDS	POUND	.000	.002	.000	.123	595.520	7.540	8.416	.000	.008	.183	1.166	.024	.000
WATERBORNE ACID	POUND	.003	.327	.047	.068	1.770	11.963	.403	.020	1.210	.338	.052	.007	.000
WATERBORNE METAL ION	POUND	.001	.082	.012	.017	229.943	3.735	.101	.005	.303	.084	.013	.002	.000
WATERBORNE CHEMICALS	POUND	0.000	0.000	0.000	0.000	17.400	.560	3.505	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	0.000	0.000	.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE LEAD	POUND	0.000	.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 63 (Concluded)

SUMMARY OF SYSTEMS

		BAUXTE MINING 868 LB	CUSTIC SODA SYSTEM 352 LB	LIME SYSTEM 240 LB	PETRO PRODUCTS 680 LB	BAUXITE REFINING 3000 LB	ALUMINUM SMELTING 2120 LB	ALUMINUM ROLLING 2380 LB	AL CLOSE FABRICA 454 LB	AL CAN BODY FARICA 1460 LB	CAN FILLING AND PLAS CARRIER	PAPER PACKAGIN 121 LB	TRANSPOR	DISPOSAL
SUMMARY OF ENVIRONMENTAL IMPACTS NAME	UNITS													
RAW MATERIALS	POUNDS	0.000	493.509	480.000	2.634	1071.000	74.200	92.276	22.302	51.246	3.582	129.005	0.000	0.000
ENERGY	MIL BTU	.294	4.810	.634	31.799	34.362	230.380	16.862	.653	38.538	12.313	2.033	7.714	.106
WATER	THOU GAL	.012	1.766	.061	6.722	1.314	39.975	15.685	.009	.928	.313	1.798	.435	.007
INDUSTRIAL SOLID WASTES	CUBIC FT	.006	1.659	.654	.162	78.512	29.336	4.319	.092	3.081	2.409	.247	.016	.000
ATM EMMISSIONS	POUNDS	3.896	21.839	10.579	31.865	176.363	1019.199	55.567	25.977	145.637	50.673	12.673	38.303	1.002
WATERBORNE WASTES	POUNDS	.057	.836	.120	17.011	912.517	65.065	30.098	.105	6.172	4.357	4.005	3.727	.058
POST-CONSUMER SOL WASTE	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	13.301
INDEX OF ENVIRONMENTAL IMPACTS NAME	STANDARD VALUES													
RAW MATERIALS	241.975	0	204	198	1	443	31	38	9	21	1	53	0	0
ENERGY	38.050	1	13	2	84	90	605	44	2	101	32	5	20	0
WATER	6.902	0	26	1	97	19	579	227	0	13	5	26	6	0
INDUSTRIAL SOLID WASTES	12.049	0	14	5	1	652	243	36	1	26	20	2	0	0
ATM EMMISSIONS	159.445	2	14	7	20	111	639	35	16	91	32	8	24	1
WATERBORNE WASTES	104.413	0	1	0	16	874	62	29	0	6	4	4	4	0
POST-CONSUMER SOL WASTE	1.330	0	0	0	0	0	0	0	0	0	0	0	0	1000
UNWEIGHTED INDEX		3	272	213	219	2189	2159	489	28	258	94	98	54	1001
WEIGHTED INDEX OF ENVIRONMENTAL IMPACTS NAME	WEIGHT													
RAW MATERIALS	.05	0	10	10	0	22	2	2	0	1	0	3	0	0
ENERGY	.40	0	5	1	33	36	242	18	1	41	13	2	0	0
WATER	.05	0	1	0	5	1	29	11	0	1	0	1	0	0
INDUSTRIAL SOLID WASTES	.05	0	1	0	0	33	12	2	0	1	1	0	0	0
ATM EMMISSIONS	.20	0	3	1	4	22	128	7	3	10	6	2	5	0
WATERBORNE WASTES	.20	0	0	0	3	175	12	6	0	1	1	1	1	0
POST-CONSUMER SOL WASTE	.05	0	0	0	0	0	0	0	0	0	0	0	0	50
WEIGHTED COMPOSITE INDEX		0	20	12	45	289	425	46	4	63	21	9	14	50

TABLE 64

IMPACTS FOR 1 TON OF EACH PROCESS - ALUMINUM SYSTEM

INPUT TO SYSTEMS

MATERIALS NAME	UNITS	BAUXITE MINING	CAUSTIC SODA SYSTEM	BAUXITEG REFINING	ALUMINUM SMELTING	ALUMINUM ROLLING	ALUMINUM CAN BODY FAB	ALUMINUM CLOSURE FAB	ALUM RECYCLE
MATERIAL WOOD FIBER	POUNDS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL LIMESTONE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	471.056	0.000
MATERIAL IRON ORE	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL SALT	POUND	0.000	2142.000	0.000	0.000	0.000	0.000	477.709	0.000
MATERIAL GLASS SAND	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL NAT SODA ASH	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL FELDSPAR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MATERIAL BAUXITE ORE	POUND	0.000	0.000	574.000	0.000	0.000	0.000	853.423	0.000
MATERIAL PROCESS ADD	POUNDS	0.000	32.050	140.000	70.000	78.200	70.200	466.825	40.000
ENERGY PROCESS	MIL BTU	.550	21.166	22.908	217.339	14.290	52.792	294.886	12.554
ENERGY TRANSPORT	MIL BTU	.027	.021	0.000	0.000	0.000	0.000	4.433	.407
ENERGY OF MATL RESOURCE	MIL BTU	0.000	0.000	0.000	0.000	0.000	0.000	29.228	0.000
WATER VOLUME	THOU GAL	.028	7.780	.876	37.713	13.292	1.271	66.531	1.068

OUTPUT FROM SYSTEMS

MATERIALS NAME	UNITS	BAUXITE MINING	CAUSTIC SODA SYSTEM	BAUXITEG REFINING	ALUMINUM SMELTING	ALUMINUM ROLLING	ALUMINUM CAN BODY FAB	ALUMINUM CLOSURE FAB	ALUM RECYCLE
SOLID WASTES PROCESS	POUND	0.000	24.070	0.000	194.000	215.000	40.000	519.994	12.000
SOLID WASTES FUEL COMB	POUND	.417	94.830	41.050	742.444	22.446	109.040	900.476	21.207
SOLID WASTES MINING	POUND	.612	422.581	3836.100	1113.600	33.669	163.560	7028.079	31.320
SOLID WASTE POST-CONSUM	CUBIC FT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-11.000
ATMOS PARTICULATES	POUND	6.759	9.430	36.916	105.291	3.002	11.372	184.271	14.557
ATMOS NITROGEN OXIDES	POUND	.812	18.639	21.686	212.089	16.268	57.776	300.554	13.200
ATMOS HYDROCARBONS	POUND	.680	7.937	12.176	121.777	11.920	59.702	275.231	9.121
ATMOS SULFUR OXIDES	POUND	.254	47.079	40.789	388.485	11.278	54.538	506.142	12.903
ATMOS CARBON MONOXIDE	POUND	.464	4.508	5.857	129.447	4.551	15.857	165.264	3.589
ATMOS ALDEHYDES	POUND	.004	.049	.083	.456	.025	.098	1.065	.060
ATMOS OTHER ORGANICS	POUND	.003	.045	.061	.547	.046	.159	.979	.058
ATMOS ODOROUS SULFUR	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ATMOS AMMONIA	POUND	.000	.000	.008	.001	0.000	0.000	.119	.005
ATMOS HYDROGEN FLOURIDE	POUND	0.000	0.000	0.000	2.610	0.000	0.000	2.744	0.000
ATMOS LEAD	POUND	.001	.000	.000	.000	0.000	0.000	.068	.000
ATMOS MERCURY	POUND	.000	.019	.001	.006	.000	.001	.012	.000
ATMOSPHERIC CHLORINE	POUNDS	0.000	4.500	0.000	0.000	0.000	0.000	1.896	0.000
WATERBORNE FLUORIDES	POUND	0.000	0.000	.489	10.100	0.000	0.000	11.346	0.000
WATERBORNE DISS SOLIDS	POUND	.123	1.835	3.188	19.786	1.872	6.345	49.796	2.350
WATERBORNE BOD	POUND	.006	.004	1.645	3.209	.001	.004	5.909	.004
WATERBORNE PHENOL	POUND	.000	.001	.037	.010	.000	.001	.091	.001
WATERBORNE SULFIDES	POUND	.000	.002	.002	.013	.000	.002	.050	.002
WATERBORNE OIL	POUND	.006	.002	.072	1.225	13.100	.002	16.905	.002
WATERBORNE COD	POUND	.000	.015	39.821	4.577	.003	.017	64.304	.014
WATERBORNE SUSP SOLIDS	POUND	.000	.009	347.013	7.113	7.132	.011	606.334	1.009
WATERBORNE ACID	POUND	.006	1.442	1.180	11.286	.341	1.658	14.551	.319
WATERBORNE METAL ION	POUND	.002	.360	143.295	3.524	.085	.414	231.856	.080
WATERBORNE CHEMICALS	POUND	0.000	0.000	11.600	.528	2.470	0.000	21.307	0.000
WATERBORNE CYANIDE	POUND	0.000	0.000	0.000	.011	0.000	0.000	.011	0.000
WATERBORNE ALKALINITY	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE CHROMIUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE IRON	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE ALUMINUM	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE NICKEL	POUND	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WATERBORNE MERCURY	POUND	0.000	.000	0.000	0.000	0.000	0.000	.000	0.000
WATERBORNE LEAD	POUND	0.000	.012	0.000	0.000	0.000	0.000	.003	0.000

TABLE 64 (Concluded)

```
                                                SUMMARY OF SYSTEMS

                                             BAUXITE  CAUSTIC   BAUXITEG  ALUMINUM  ALUMINUM  ALUMINUM  ALUMINUM  ALUM
                                             MINING   SODA      REFINING  SMELTING  ROLLING   CAN BODY  CLOSURE   RECYCLE
                                                      SYSTEM                                  FAB       FAB
SUMMARY OF ENVIRONMENTAL IMPACTS
        NAME                         UNITS

        RAW MATERIALS              POUNDS        0.000  2174.050   714.000    70.000    78.200    70.200  2269.013    40.000
        ENERGY                     MIL BTU        .478    21.187    22.908   217.339    14.290    52.792   328.548    12.961
        WATER                      THOU GAL       .028     7.780      .876    37.713    13.242     1.271    66.531     1.068
        INDUSTRIAL SOLID WASTES    CUBIC FT       .014     7.310    52.342    27.676     3.660     4.220   114.055      .871
        ATM EMMISSIONS             POUNDS        8.977    96.207   117.575   961.508    47.090   199.503  1458.344    53.575
        WATERBORNE WASTES          POUNDS         .131     3.682   608.345    61.382    25.507     8.455  1022.464     3.781
        POST-CONSUMER SOL WASTE    CUBIC FT      0.000     0.000     0.000     0.000     0.000     0.000     0.000   -11.800
INDEX OF ENVIRONMENTAL IMPACTS
        NAME                       STANDARD
                                    VALUES

        RAW MATERIALS              135.310           0      1607       528        52        58        52      1677        30
        ENERGY                      32.886           2        64        70       661        43       161       999        39
        WATER                        5.414           0       134        15       649       229        22      1144        18
        INDUSTRIAL SOLID WASTES     11.250           0        65       465       246        33        38      1014         8
        ATM EMMISSIONS             144.737           6        66        81       664        33       138      1008        37
        WATERBORNE WASTES          102.354           0         4       594        60        25         8       999         4
        POST-CONSUMER SOL WASTE     -1.180           0         0         0         0         0         0         0     --1000

        UNWEIGHTED INDEX                             8      1940      1753      2332       421       419      6841       864
WEIGHTED INDEX OF ENVIRONMENTAL IMPACTS
        NAME                        WEIGHT

        RAW MATERIALS                  .05           0        80        26         3         3         3        84         1
        ENERGY                         .40           1        26        28       264        17        64       400        16
        WATER                          .05           0         7         1        32        11         1        57         1
        INDUSTRIAL SOLID WASTES        .05           0         3        23        12         2         2        51         0
        ATM EMMISSIONS                 .20           1        13        16       133         7        28       202         7
        WATERBORNE WASTES              .20           0         1       119        12         5         2       200         1
        POST-CONSUMER SOL WASTE        .05           0         0         0         0         0         0         0       -50

        WEIGHTED COMPOSITE INDEX                     2       130       213       456        45       100       994        24
```

Table 63 summarizes all operations for 1 ton of cans. All the operations and systems listed refer to the production of the can cylinder, closure and associated packaging. It is clear that the steps of bauxite refining and aluminum smelting dominate the environmental impact profile of the aluminum can system, representing 29 and 42 percent, respectively, of the impacts for can systems.

The most serious impact in bauxite refining is waterborne wastes, primarily suspended solids from red mud disposal. For the smelting operation, the high use of electric energy is by far the most important factor. This use also results in a rather high value for atmospheric emissions from generating plants.

Table 64 is a printout for 1 ton of product from each operation. Its purpose is to convert raw data into environmental profiles for each step. Data for 1 ton of each operation are presented in the following sections of this chapter.

Table 62 compares the impacts for the conventional aluminum can system with four hypothetical recycle levels. These are discussed in Section H.

B. Bauxite Mining

Aluminum is the most widely distributed metal in the earth's crust, with only the nonmetallic elements oxygen and silicon surpassing it in abundance. However, bauxite ore is at the present time the only commercially exploited source of aluminum. Although other types of earth, including ordinary clay, contain aluminum, industry economics favor bauxite as the preferred ore.

Bauxite is formed by the action of rain and erosion on materials containing aluminum oxide (alumina). The heavy rainfall and warm temperatures of the tropics provide the most nearly ideal conditions for this process, and most of the world's bauxite is mined in these regions. Although the United States is the world's largest consumer of bauxite, nearly 90 percent of the bauxite used here is imported.

Most bauxite is mined by open-pit methods. In Jamaica, the leading producer of bauxite, the ore lies close to the surface, and only the vegetation and topsoil need to be stripped. In Arkansas, the top domestic producing region, open-pit mining is also used, with stripping ratios of 10 feet of overburden to 1 foot of ore considered minable. Underground mining is employed at one location in Arkansas, and this method is the most common in Europe.[95]

In the present study, only domestic environmental impacts are considered, so the data presented here refer only to the mining of domestic bauxite. The transportation figures, however, include domestic transportation of imported bauxite. Table 65 presents the data relating to the mining of 1 ton of domestic bauxite ore.

TABLE 65

DATA FOR THE MINING OF 1 TON BAUXITE ORE

		Source
Energy		89
Distillate	0.122 gal.	
Residual	0.0737 gal.	
Gasoline	0.194 gal.	
Natural gas	398 cu ft	
Electric	7.03 kwhr	
Water Volume	15.7 gal.	90
Atmospheric Emissions		
Particulates	6.7 lb	52
Transportation		67,86
Truck	10 ton-miles	
Barge[a]	950 ton-miles	

---

[a] Domestic transportation of imported ore.

It is clear that the environmental impacts of bauxite mining are relatively small. This is even more evident upon examination of Table 63, which indicates that domestic mining of bauxite accounts for less than one-half of 1 percent of the total impact of the aluminum can system, so that index values, in every impact category, are shown as zero in the weighted index tables.

Mining solid wastes which are often associated with ore mining are not included here, but are instead counted in the refining operation, where they show up either as suspended solids in wastewater effluents or as solid wastes. Thus, for domestic refining operations, the wastes from imported ore are counted along with those from domestic ore. The way in which these data are treated in this study is further discussed in Section D of this chapter.

C. Caustic Soda Manufacture

The refining of bauxite ore to alumina employs strong caustic soda solutions. The major raw material for caustic soda is salt, and it is assumed here that this is obtained by the mining of rock salt. Rock salt mines are widely distributed throughout the United States, with 17 states reporting production in 1969.[102]

Data pertaining to the mining of 1 ton of rock salt are presented in Table 66.

TABLE 66

DATA FOR THE MINING OF 1 TON ROCK SALT

		Source
Energy		89
Residual	0.11 gal.	
Gasoline	0.01 gal.	
Natural gas	168 cu ft	
Electric	85 kwhr	
Water Volume	521 gal.	89
Mining Wastes	262 lb	67
Transportation		67
Rail	300 ton-miles	
Truck	50 ton-miles	

Caustic soda (sodium hydroxide) is manufactured from salt by an electrolytic process. The aqueous sodium hydroxide solution is electrolyzed to produce caustic soda, chlorine, and hydrogen gas. The chlorine and caustic soda each account for about half the output of the process, with hydrogen amounting to only 1 percent by weight. Therefore, half the impacts of the process are allocated to chlorine production and half to caustic soda production. The chlorine is a useful product in other manufacturing processes, so its impacts are not included in the aluminum can system. The impacts allocated to caustic soda manufacture are presented in Table 67.

TABLE 67

DATA FOR THE MANUFACTURE OF 1,000 POUNDS CAUSTIC SODA

		Source
Virgin Raw Materials		12,67
Salt	1,071 lb	
Process additives	16 lb	
Energy - Electric	722 kwhr	12,67
Water Volume	3,475 gal.	11
Process Solid Wastes	12 lb	67
Process atmospheric emissions		
Chlorine	4.25 lb	67
Mercury	0.009 lb	67
Waterborne Wastes		67
Lead	0.006 lb	
Mercury	0.00013 lb	
Dissolved solids	0.2 lb	

D. Refining of Alumina

Before it can be used in the manufacture of metallic aluminum, bauxite ore must be refined to nearly pure aluminum oxide, Al_2O_3, usually called alumina. The method used to accomplish this is called the Bayer process, which is used almost exclusively. The bauxite is crushed and dissolved in digesters, using strong caustic soda and lime solutions. The undissolved residue, known as red mud, is filtered out and constitutes a major disposal problem for alumina refiners. Sodium aluminate remains in solution, where it is hydrolyzed and precipitated as aluminum hydroxide, which is then calcined to alumina, generally in a rotary kiln.

The unweighted indices for bauxite refining (Table 63) indicate that waterborne wastes and solid wastes constitute the largest parts of the environmental profile. Both of these categories consist largely of mining wastes, the roughly 45 percent of bauxite that is discarded after the sodium aluminate is removed in solution. The manner in which wastes are handled determines whether they show up as waterborne wastes or as solid wastes. If these red muds are simply discharged into a river, they are of course a major water pollutant. In some cases, however, they are impounded in settling ponds, where they end up as solid wastes on land. The figures used in the present study are based on data reflecting current practice. It should be noted, however, that there is an increasing tendency, in some cases required by legislation, to impound the red muds as solids. Changes in the ratio between waterborne and solid wastes would be reflected in the weighted indices, where waterborne wastes are given more weight. Current industry projections call for reductions of as much as 97 percent in the waterborne wastes of alumina plants by mid-1975.[81]

The virgin raw materials category reflects only that portion of the bauxite ore which is mined domestically. The most recent data put this amount at about 10.4 percent of domestic consumption. Impact data for alumina refining are presented in Table 68.

TABLE 68

DATA FOR THE PRODUCTION OF 1 TON OF REFINED ALUMINA

		Source
Virgin Raw Materials		35,102
Domestic Bauxite	574 lb	
Other	140 lb	
Energy		88
Coal	0.140 ton	
Distillate	6.56 gal.	
Residual	12.2 gal.	
Natural gas	5,400 cu ft	
Electric	700 kwhr	
Water Volume	479 gal.	67
Mining Solid Wastes	3,722 lb	67
Atmospheric Emissions		
Particulates	24.4 lb	52
Waterborne Wastes		75,76,79,81
BOD	1.64 lb	
COD	39.8 lb	
Suspended solids	397 lb	
Chemicals	11.6 lb	
Metal ions	153 lb	
Fluorides	0.489 lb	
Oil and grease	0.0698 lb	
Phenols	0.0356 lb	
Transportation		67
Rail	600 ton-miles	
Barge	600 ton-miles	
Truck	68 ton-miles	

E. Aluminum Smelting

The reduction of refined alumina to metallic aluminum results in the largest environmental impact of any process in the production of aluminum cans. When both the can body and the top are considered, these smelting operations account for more than 42 percent of the total environmental impact of the aluminum can system.

The principal cause of the high environmental impacts associated with aluminum smelting is the high consumption of electrical energy required to effect the separation of aluminum from its oxide. The process is carried out in a long series of electrolytic cells, carrying direct current. The alumina is dissolved in a molten bath of cryolite and aluminum fluoride. Carbon anodes carry the current to the solution, and a carbon cathode lining carries the current out of the solution and on to the next cell. The anodes are consumed during the reaction at a rate of approximately 0.75 ton of material per ton of aluminum produced. The principal products of the reaction are carbon dioxide, which is evolved as a gas, and elemental aluminum which settles to the bottom of the cell and is periodically drained off.

Although there are significant pollution problems at the smelter site, most of the impacts in the categories of atmospheric emissions, waterborne wastes, and solid wastes result from the generation of electricity and the mining of coal for fuel in electrical generation. It is clear, therefore, that the extremely high electrical requirement is the overriding environmental concern in aluminum smelting operations.

The emission factors for electrical generation--which are used for every system in this study--are based on a national average mix of fuels for electrical generation, including hydroelectric power. It is true that the aluminum industry uses a relatively high proportion of hydroelectric power. It is our judgment, however, that a study such as this should not distinguish between different "kinds" of kilowatt hours, since if the hydroelectric power were not used by the aluminum industry, it would be available as an alternative to power generated with fossil fuels. In cases where electricity is generated by the aluminum companies for captive use in their plants, the power is not included in the electrical energy category. Rather, the fuels used to generate that power are included separately; and, in this latter case of self-generated power, full credit is given for hydroelectric generation to the extent it occurs.

The primary pollution problem at the smelter site is fluoride emissions from the cryolite baths. These occur as both particulate and gaseous atmospheric emissions, and as waterborne wastes. Carbon monoxide, while constituting a greater weight percent of the emissions, is of a lower order of toxicity and of secondary concern to smelter operators.

A newly developed process is said to be able to produce aluminum with about 30 percent less power, while eliminating fluoride emissions altogether. It would still use an electrolytic process, but the alumina would first be converted to aluminum chloride. The products of the electrolysis would be molten aluminum and chlorine, which would then be reused in the chlorination step. Although the new process appears to hold promise for the long run, there is not indication that it will have a significant effect on the industry's practices in the foreseeable future.[17]

The data used in calculating the environmental impacts of aluminum smelting are presented in Table 69.

TABLE 69

DATA FOR THE SMELTING OF 1 TON OF ALUMINUM

		Source
Virgin Raw Materials[a]		
Process additives	70 lb	35
Energy		88
Distillate	0.465 gal.	
Residual	1.37 gal.	
Natural gas	40,000 cu ft	
Electric	12,800 kwhr	
Water Volume	34,800 gal.	81
Solid Wastes	194 lb	58,67
Atmospheric Emissions		81
Particulates	30.6 lb	
HF gas	2.61 lb	
SO_x	18.8 lb	
Hydrocarbons	4.19 lb	
CO	75.0 lb	
NO_x	1.36 lb	
Waterborne Wastes		81
Suspended Solids	7.04 lb	
Fluorides	10.1 lb	
BOD	3.18 lb	
COD	4.46 lb	
Cyanide	0.0107 lb	
Ammonia	0.528 lb	
Metal ions	0.702 lb	
Oil and grease	1.21 lb	

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[a] Coke and pitch production, for anode manufacture, is counted as a separate system. See data for refinery products in Chapter III.

F. Aluminum Rolling

Aluminum ingots from the smelter, along with some new scrap aluminum, are processed by rolling mills into aluminum alloy sheet. The alloying materials, mainly magnesium, are assumed to be added at the rate of less than 2 percent of the material input. The scrap used here is not postconsumer scrap, but is industrial scrap, usually from can fabricating plants. The post-consumer scrap considered in the recycle options in Section I is in addition to the new scrap normally used in conventional aluminum cans. Table 70 contains the data for rolling 1 ton of sheet for use in aluminum can bodies and tops.

TABLE 70

DATA FOR THE ROLLING OF 1 TON ALUMINUM SHEET

		Source
Virgin Raw Materials		67
Process Additives (alloying materials and lubricating oils)	78.2 lb	
Energy		67
Natural Gas	7,020 cu ft	
Electricity	387 kwhr	
Water Volume	13,100 gal.	67
Atmospheric Emissions		52
Particulates	0.594 lb	
Solid Wastes	215 lb	58,67
Waterborne Wastes		
Suspended Solids	7.13 lb	58,67
Phosphates	2.97 lb	
Oils and Grease	13.1 lb	
Transportation		67
Rail	1,420 ton-miles	
Truck	12.5 ton-miles	

G. Can Fabrication

The aluminum can body, which forms the sides and bottom of the container, is drawn from a single piece of aluminum sheet. The can top, also made from aluminum sheet, does not have to be drawn, and its fabrication therefore requires substantially less energy than does the can body. The can top and can body are not joined at the fabricating plant, but rather at the filling plant, after the beverage is in the can.

Tables 71 and 72 contain the basic data for the fabrication of the aluminum can body and top, respectively.

TABLE 71

DATA FOR THE FABRICATION OF 1 TON ALUMINUM CAN BODIES

Virgin Raw Materials	
Process additives	70.2 lb
Packaging	121 lb
Energy	
Natural gas	21,600 cu ft
Electricity	1,880 kwhr
Water Volume	563 gal.
Atmospheric Emissions	
Hydrocarbons	19.8 lb
Solid Wastes	40 lb
Transportation	
Truck	110 ton-miles
Rail	97 ton-miles
Barge	11 ton-miles

Source: 67

TABLE 72

DATA FOR THE FABRICATION OF 1 TON ALUMINUM CLOSURES

Virgin Raw Materials	
Process Additives	82.6 lb
Packaging	11.6 lb
Energy	
Natural Gas	1,000 cu ft
Electricity	85 kwhr
Atmospheric Emissions	
Hydrocarbons	88 lb
Solid Wastes	13 lb

Source: 67

H. Recycle Options

Considerable environmental gains can be made by using recycled aluminum as opposed to virgin aluminum used in a product. Table 73 summarizes the environmental data for a secondary smelter recycling aluminum cans. Included are operations for shredding and transporting the cans to a smelter as well as smelter data. A credit is given for the removal of the cans from the solid waste stream.

Two important assumptions have been made which make this recycling profile more favorable to aluminum recycling than for other situations. One assumption is that the cans are carried back to a grocery store and further carried on to processors by backhaul trucks. Thus, the cans are assumed to ride "piggy back" on transportation already occurring for another purpose. For voluntary collection centers where cars may be driven long distances for the sole purpose of delivering cans, this is not true. Some details concerning this possibility can be found in Volume I.

The second assumption is that the scrap recycled is "clean" cans. If significant impurities and alloying materials are present in aluminum scrap, then the impacts of smelting are greater. Highly corrosive and environmentally damaging materials such as chlorine may be required, as well as higher energy requirements. Much more serious air pollution can result, as well as considerably more solid waste. Thus, the recycling options considered here probably represent a "most favorable" situation for aluminum recycling.

TABLE 73

DATA FOR RECYCLING ONE TON ALUMINUM FROM CLEAN SCRAP

Materials	
Fluxes	40 lb
Energy	
Distillate	5.7 gal.
Residual	5.3 gal.
Natural gas	4,651 cu ft
Electricity[a]	360 kwhr
Water	800 gal.
Industrial Solid Wastes	12 lb
Post-Consumer Solid Waste[b]	-2,000 lb
Atmospheric Emissions	
Particulates	12 lb
Waterborne Wastes	
Suspended Solids	1 lb
Transportation	
Rail	500 ton-miles

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[a] Includes 250 kwhr for shredding cans.

[b] This represents 2,000 lbs of cans removed from the solid waste stream.

Source: 67,88

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